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THE ECONOMIC VALUE OF REMOTE SENSING OF EARTH RESOURCES FROM SPACE: AN ERTS OVERVIEW AND THE VALUE OF CONTINUITY OF SERVICE

VOLUME III

INTENSIVE USE OF LIVING RESOURCES: AGRICULTURE

PART I:

OVERVIEW

Prepared for the
Office of the Administrator
National Aeronautics and Space Administration
Under Contract NASW-2580

October 31, 1974

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NOTE OF TRANSMITTAL

This resource management area report is prepared for the Office of the Administrator, National Aeronautics and Space Administration, under Article I.C. of Contract NASW-2580. It provides backup material to the Summary, Volume I, and the Source Document, Volume II, of this report. The interested reader is referred to these documents for a summary of data presented herein and in the other resource management areas.

The data presented in this volume are based upon the best information available at the time of preparation and within the resource of this study. This includes a survey of existing studies plus Federal budgets and statutes. Throughout the analysis, a conservative viewpoint has been maintained. Nonetheless, there are, of course, uncertainties associated with any projection of future economic benefits, and these data should be used only with this understanding.

ECON recognizes the contributions of Alain L. Kornhauser and Lawrence Wilson who authored this volume.

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ABSTRACT

Contained in this volume is a detailed assessment of potential economic benefits obtainable from a state-of-the-art ERS system in the resource area of intensive use of living resources - agriculture. A spectrum of equal capability (cost saving), increased capability and new capability benefits are quantified. Major public benefits derive primarily from ERS's capability of providing improved crop acreage measurements. These benefits are estimated via ECON-developed models of the agricultural marketplace and include benefits of improved production and distribution of agricultural crops. Equal capability benefits accrue mainly to various branches of the USDA. Additional increased capability benefits and new capability benefits result from a reduction of losses due to disease and insect infestation given ERS's capability to distinguish crop vigor and from the improvement in world trade negotiations given ERS's worldwide surveying capability. Both hard (well-founded in rigorous quantitative analysis) and soft (less rigorous parametric analysis) benefits are presented. Total estimated annual hard benefits are between \$252 and \$554 million. Additional soft annual benefits range between \$444 and \$957 million. Benefits to the world community from worldwide distribution of ERS data are potentially in the tens of billions of dollars.

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1.0 INTRODUCTION AND OVERVIEW: AGRICULTURE

The present annual value of United States living resources is estimated to be over $60 billion per year, of which over $25 billion represents the value of agricultural crops and $35 billion represents the value of livestock. The value of these resources is magnified by their present scarcity in the world market place. At the recently held World Population Congress in Bucharest (August, 1974) it was estimated that the world holds, at present, reserves of food for only 27 days. This low inventory level has resulted in price inflation and price fluctuation that is harmful to the consumer as well as the producer. It is imperative that these resources be managed, if not optimally, at least better than they are at the present. At present, economic losses to the public at large resulting from imperfect management of these resources can be attributed directly to incomplete, insufficient and erroneous knowledge of the state (e.g., expected production, both domestic and worldwide; pest and disease infestation; etc.) of these resources.

At present, the management of these resources can be significantly improved through improved information. The Statistical Reporting Service (SRS) and the Foreign Agricultural Service (FAS) of the United States Department of Agriculture (USDA) presently spend over $26 million per year in gathering statistics on agricultural crops. In many cases, their accuracy can and may be improved. For example, Figure 1 presents data on estimates of 1974 production of corn, wheat and soybeans. The data indicate greater than 10% variations in production forecasts between the highest 1974 estimate and the August forecast for each of these crops. The testimony of Agriculture Secretary Butz at the House Appropriations Committee Hearings for FY 75* provides further insights:

> Mr. Whitten:
>
> ...The recent Russian wheat sale has again raised questions about the Foreign Agricultural Service. Russia was 20 billion bushels of wheat short, we sold them 30, which gave them the 10 billion extra bushels of wheat to use around the world to gain political leverage.

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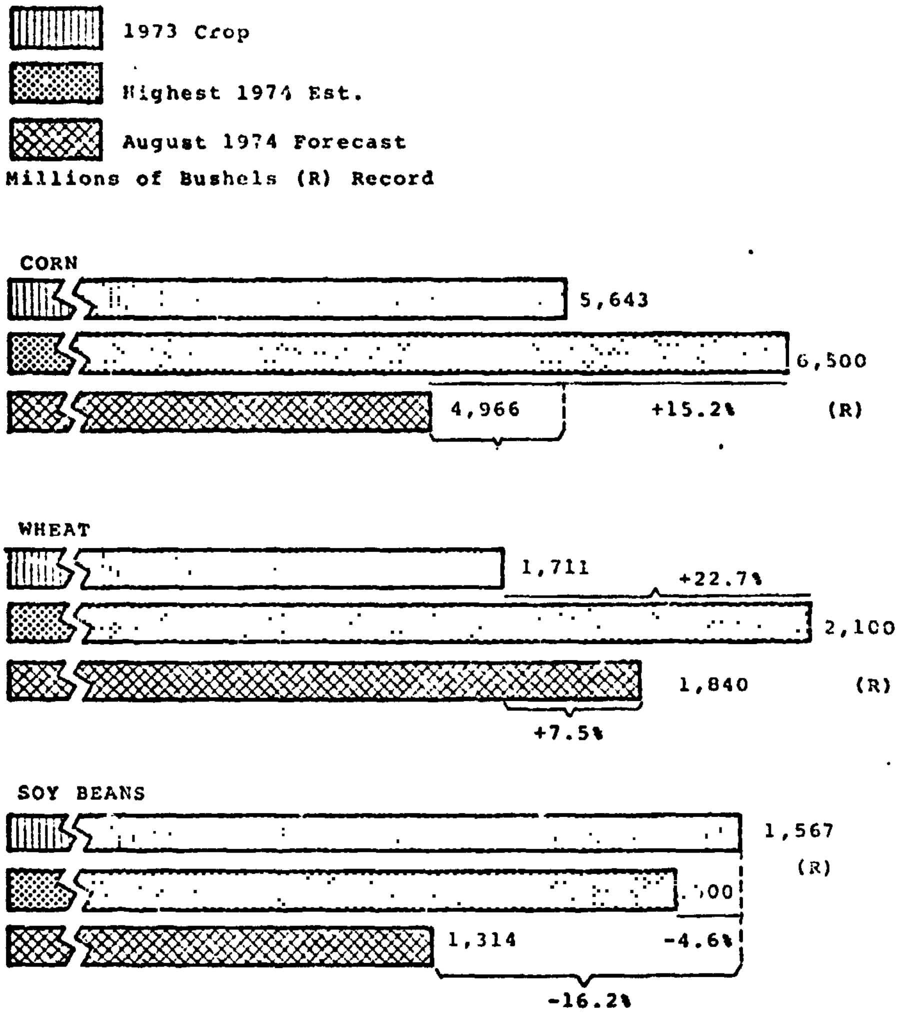
* House Committee on Appropriations, Agriculture-Environmental and Consumer Protection Appropriations for 1975, Part 1, pp.14.



Source: Commodities Research, Department of Agriculture

Figure 1 USDA 1974 Crop Forecast Performance as of August 13, 1974

Our foreign agricultural attachés were the ones who should have informed us about the fact that we had the only wheat surplus in the world....I don't know anything specific about the sale, but I am saying the Foreign Agricultural Service is the organization that could or should have kept you informed, if I understand it properly, and yet they seem to have broken down. Yet now you want to put the sales program under that group which has just made a major mistake.

Secretary Butz:

They kept us informed to the extent it was humanly possible to do so.

This exchange illustrates how more accurate or timely information can lead to better decision making and result in economic gains that have been estimated to be at least $200-500 million and possibly well over $1 billion, whenever such unique events occur.

Better information can result in improved management of living resources through;

1) Better domestic distribution of products
2) Better allocation of production resources
3) Reduction in price fluctuations
4) Reduced production losses
5) Better import-export decisions
6) Better allocation of foreign aid

A state-of-the-art ERS system can provide improved information on li ng resources, primarily in the area of agricultural crops. The Goddard Agricultural Task Force has shown that remote sensing by satellite can provide better estimates of crop acreage and yield than those made by the SRS and give strong indication that an ERS system can monitor crop vigor.* Application of such ERS data to better management of crops can produce benefits in two main areas:

1) Cost savings to federal and state agencies in obtaining the same quality data on the state (e.g., acreage, yield, vigor) of living resources. These have been estimated in Appendix A of this volume to amount possibly to $58 million per year.

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* Wood, D. B., The Use of ERTS for Crop Production Forecasts, GSFC Task Force on Agriculture, Final Report, August 1974.

2) Public benefits derived from better management decisions based on improved or previously unavailable data on the state of living resources. Potential benefits to the American public, derivable from a state-of-the-art ERS system, are estimated herein to be at least $247 million to possibly $1 billion per year. (Potential benefits to the World Community from universal availability of the data from an integrated ERS system are possibly one order of magnitude larger.)

1.1 Summary of Cost Saving Benefits

In this volume, U.S. cost saving benefits are estimated mainly at the Federal level and benefits accrue mainly to USDA activities. These amount to potentially $37 million per year in domestic soil survey activities which are presently subcontracted by the Soil Conservation Service (SCS) of USDA to private soil surveying firms.* By subcontracting this activity to the ERS system the SCS can realize benefits of up to $37 million per year, say by 1985.

Additional transfer of activities to an ERS system could save 1) the Federal Crop Insurance Corporation (FCIC) $1.3 million per year in the costs of assessing the damage to agricultural crops,** and, 2) the Agricultural Stabilization and Conservation Service potentially $15.8 million per year in expenditures for the enforcement of the provisions of the Agricultural Adjustment Act of 1938,*** should these provisions still be part of U.S. agricultural policy in the 1980s.

Significant additional cost savings could result if state DOA's made use of ERS derived agricultural data ($4.2 million per year in the gathering of state and local agricultural statistics****).

The cost savings indicated above are realizable in that it is expected that an ERS system could indeed supplant the present data gathering procedures noted here. On the other hand, it is not legitimate to claim an additional $26 million

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* See Appendix A, RMF 1.1.2 and 1.1.3
** See Appendix A, RMF 1.6.5
*** See Appendix A, RMF 1.9.2
**** See Appendix A, RMF 1.?.1

annual benefit (present expenditures by SRS of USDA in obtaining data) because it would be unwise for the SRS to abandon its present efforts in obtaining agricultural data.

1.2 Summary of Benefits of Improved Management Decisions

Better management of agricultural resources is possible, given ERS's ability to monitor agricultural crops.* An example of ERTS ability to monitor crops can be seen in Figure 2, an image of the Imperial Valley, California. Increased capability benefits result primarily from improvements to USDA's crop production forecasts through the expected ERS capability of improved acreage (and potentially, yield) estimates. Better inventory depletion and distribution decisions are estimated to return between $247 and $723 million in annual public economic benefits.** In addition to the rather detailed and in-depth case studies more speculative considerations may also include the following:

- The ability of ERS to monitor crop vigor on, say, a weekly basis, can result in substantial benefits by reducing crop damage losses. Market value losses of the fifteen leading agricultural crops due to disease, insect and weed infestation are presently $8 billion per year. It is expected that better allocation of insecticides, herbicides, and fertilizers possible from improved data on the location and extent of infestations can reduce crop losses due to insects and disease by from 1% to 10%. Crop losses due to weeds could be reduced by from 0.1% to 1.0%. Such loss reductions yield public benefits of $38 - $354 million per year in the area of crop disease prevention, $18 - $175 million per year from reduction in losses due to insect infestation, and $3.4 - $23.7 million per year resulting from weed infestation loss reduction.

- An additional $200-500 million in public benefits could accrue every two-to-four years from the more timely and more accurate definition of non-recurring insect infestation and/or blights.

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* For an ERTS image of the San Joaquin Valley, see Figure 1.2, Volume I of this study.

** Based on ECON-developed economic models presented in Appendix A, RMF 1.2.1 and Volume III, Parts II and III.

- Benefits derived from improved management decisions, based on an ERS capability of providing previously unavailable data, are also substantial. Data provided by ERS may enable farmers to make better

Figure 2 ERTS Image of the Imperial Valley, California Illustrating Crop Monitoring

allocations of agricultural lands. The public benefits due to improved allocation of agricultural lands are estimated to be $15.4 - $118.8 million per year.* More wide-spread soil surveys may enable the Soil Conservation Service to better manage lands, possibly reducing annual soil erosion losses by 10%. Such reductions would lead to $82.2 million in annual public benefits. The single largest benefit results from an ERS capability for providing data that would enable one to accurately estimate world-wide agricultural production. Better international trade decisions, resulting from previously unavailable accurate estimates of worldwide crop production forecasts, would yield between $265 and $471 million in annual benefits to the American public.** An additional $200-500 million in public benefits (based on previously unavailable accurate worldwide crop proudction forecasts) are estimated to accrue every two-to-four years from better unique large scale international trade agreements such as the 1972 "Russian Wheat Deal."***

- Speculative benefits of presently unavailable world-wide agricultural production information and management if used by the worldwide community could yield the world community as much as $35.8 billion per year in annual benefits (not included anywhere in this assessment).

The above estimates are summarized in Table 1 below. Also presented therein are a list of other potential but unquantified sources of benefits, and the identification of areas in which an ERS system is expected either not to be applicable (livestock inventories and related livestock allocation decisions) or to yield only insignificant benefits (monitoring new agricultural practices). It is important to emphasize that the benefits quantified are based on (demonstrated) ERS state-of-the-art capabilities of providing either increased or new data on the state of living resources.

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* See Appendix A, RMF 1.4.1

** Based on an ECON-developed economic model, See Appendix A, RMF 1.2.2

*** See Appendix A, RMF 1.7.3

Table 1: Magnitudes and Types of Net Annual Benefits by Resource Management Activities-Intensive Use of Living Resources: Agriculture

Resource Management Function	Benefits, $ millions (1973) Equal Capability	Increased Capability	New Capability****
1.1 Cartography, Thematic Maps and Visual Displays			
1.1.1 Worldwide Survey of Agricultural Land		(Not U.S.)	
1.1.2 Thematic Mapping by Crop Type & Soil Type	(3.5)[a]		
1.1.3 Domestic Soil Surveys	(33.5)		
1.2 Statistical Services			
1.2.1 Domestic Crop Acreage and Yield Measurements:	4.2[b]		
(a) Distribution Effects		106-247 (0-174)	
(b) Integrated Effects Minus Distribution Effects			141-302[c]
1.2.2 Worldwide Acreage and Yield Measurements:			
Distribution Effects (U.S. import, export)			(265-471) + additional non-U.S.
1.4 Allocation			
1.4.1 Allocation of Agricultural Land to Specific Crops			(15.4-118.8)
1.5 Conservation			
1.5.1 Soil Conservation			(82.2)
1.6 Damage Preservation and Assessment			
1.6.1 Agricultural Crop Disease Prevention		(38)[d]	
1.6.2 Agricultural Crop Insect Infestation Prevention		(18)[d]	
1.6.3 Agricultural Crop Weed Infestation Prevention		(2.4)[d]	
1.6.4 Agricultural Crop Stress Prevention		See RMF 3.4.4	
1.6.5 Assessment of Damage to Agricultural Crops due to Disease, Insects & Weed Infestation, Stress, Frost & Other Weather Phenomena	1.31	Unquantified	

a. Parentheses imply soft benfit estimates
b. Hard benefits from cost savings to state agriculture statistical reporting services
c. Total hard benefits lower limit of about $251 million derivable from a variety of effects, See R.M.F. 1.2.1 for explanation.
d. For conservatism, only lower limit is included here.

Table 1: Magnitude and Types of Net Annual Benefits by Resource Management Activities-Intensive Use of Living Resources: Agriculture (cont'd)

Resource Management Function	Benefits, $ millions (1973)		
	Equal Capability	Increased Capability	New Capability
1.7 Unique Event Recognition and Early Warning			
1.7.1 Reduction in Crop Damage Due to Massive Insect Infestation			e
1.7.3 Unique International Trade Events			f
1.8 Research			
1.8.2 Monitor Remedial Actions Taken in Areas Subject to Climatological & Soil Changes			See RMP 1.5.1
1.9 Administrative, Judicial, and Legislative			
1.9.1 Monitor Compliance with Federal & Local Agricultural Regulations		Small	
1.9.2 Monitor Compliance with Federal Farm Income Stabilization Programs	(15.8)		
Total:			
Hard benefits documented in ECON Case Studies	5.5	106-247	141-302
Soft Benefits	(52.8)	(58.4-232.4)	(363-672)

e Potential benefits of up to $200-500 million every 2-4 years as periods of controllable stress might occur, but not counted in totals shown here.

f Potential benefits of up to $200-500 million every 2-4 years as unique events occur, but not counted in totals shown here.

1.3 Cartography, Thematic Maps and Visual Displays

Identification and classification of land and soil resources can lead to substantial benefits when applied to the allocation of these resources. At present the U.S. and most other countries have substantial efforts in these data collection areas. It is felt that a space-based ERS system could substantially reduce the cost of obtaining such data.

Quantified in this section are potential (1985) cost savings benefits to various branches of the USDA as well as to the United Nations resulting from the transfer of cartography and mapping duties to a space-based ERS system. Only those functions that a state-of-the-art ERS system could perform are considered herein. Demonstrated performance of ERS relevant to this section includes:

1) Identification and classification of crop type and acreage*
2) Thematic mapping of soil types**
3) Monitoring of pest breeding grounds***

The potential (1985) annual benefits have been estimated:

1) Worldwide survey of Agricultural Land:

   ($80-335 million) in increased capability benefits that accrue to many countries.

2) Thematic Mapping by Crop Type and Soil Type:

   (3.5 million) in equal capability benefits in cost savings to the SCS of USDA

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* As presented in Wood, D. B., The Use of ERTS for Crop Production Forecasts, Task Force on Agriculture Forecasting, August 1974, GSFC.

** Seevers, P. M. et al, Evaluation of ERTS-1 Imagery in Mapping and Managing Soil and Range Resources in the Sand Hills Region of Nebraska.

*** Pedgley, D. E., "ERTS Surveys a 500-km^2 Locust Breeding Site in Saudi Arabia". Third ERTS Symposium Proceedings; December 1973.

3) Domestic Soil Surveys:

($33.5 million) saved by the SCS of USDA in completing its soil mapping of 1.72 million km^2 of U.S. lands.

4) Monitor Agricultural Land Use Changes:

No benefits have been computed; benefits of an ERS system would accrue slowly over long periods.

5) Regional Pest and Weed Surveys:

Benefits are counted as part of RMF's 1.6.2 and 3. Total benefits for this RMF classification are (in $ million):

Summary of Benefits:

Equal Capability	Increased Capability	New Capability
(37.0)*	(80-335)*	0

1.4 Statistical Services

Statistical services in agricultural and livestock resources are of primary importance to the efficient distribution of these resources. The USDA alone spends over $26 million per year in the area of crop production estimates. States and practically all other countries of the world also engage in gathering detailed agricultural statistics for use in production forecasts. Unfortunately the accuracy of these forecasts is limited. Due to errors in these forecasts economic losses result from:

1) Distorted and drastic price movements which cause large private costs and costs to society.

2) Timelags in government policy that would adjust for surpluses and shortfalls.

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* "Soft" benefits distributed over world nations. Throughout this volume, all benefits shown in parentheses are "soft" and were obtained by rough order of magniture analyses.

3) Inefficient use of transportation, storage and processing facilities.

In the past decades, very extensive changes have taken place in 1) total crop acreage and 2) type of crops grown in the United States (e.g., soybeans). *Increases* and *decreases* in cropland acreage between 1944 and 1964 are shown in Figure 3. Each dot in Figure 3 stands for a change of 10,000 acres in cropland. Since 1964, and particularly in the past few years, and years to come, with a return to an open market policy in U.S. agriculture and widely fluctuating world prices these dynamic changes can but only increase. The shift of rural lands to other uses in the 1959 to 1969 period is shown in Figure 4. The average *annual* shift in land acreage from rural to other uses was 2.2 *million* acres.

The year-by-year and month-by-month monitoring of these changes - and resulting changes in food supply - are one key ERS capability. The value of knowing these changes *more timely* and *more accurately* is the topic of two in-depth ECON case studies (Parts II and III of this volume).

Even though an ERS system would be of little use in performing livestock inventories, a state-of-the-art system can lead to large benefits by providing improved domestic crop acreage, and possibly yield statistics. Very large annual benefits can result from accurate worldwide crop acreage and yield statistics.

In this part, an ECON-developed model of the agricultural market is used to estimate the benefits of improved agriculture statistics for wheat and soybeans. An ECON-developed model that provides rough order-of-magnitude estimates of benefits is used to estimate benefits for all other agricultural crops.

Extensive documentation is presented in Part II and Part III of this volume on the value of ERS's capabilities in this area and the economic models used in estimating benefits. The annual benefits of the application of improved agricultural data in improving the distribution of agricultural crops to the United States society are:

1) If the ERS System provides domestic statistical data only, benefits to the U.S. are at least in the range of $251-553 million, mainly for wheat and soybeans, plus possible additional benefits of up to $174 million for crops other than wheat and soybeans.

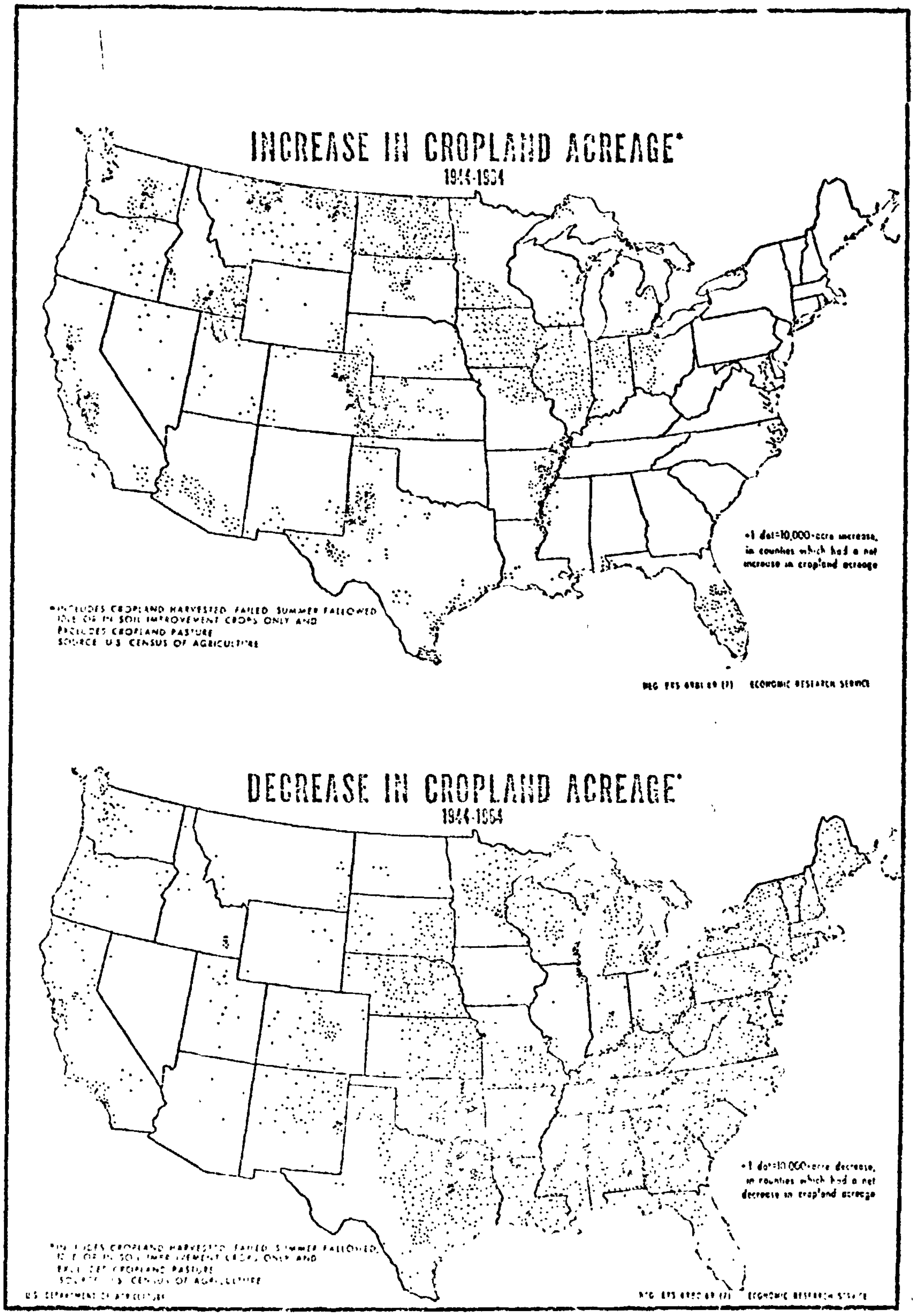

Figure 3 Cropland Acreage Changes, 1944-64

Source: U.S. Department of Agriculture, REG ERS 6980-69(7) Economic Research Service

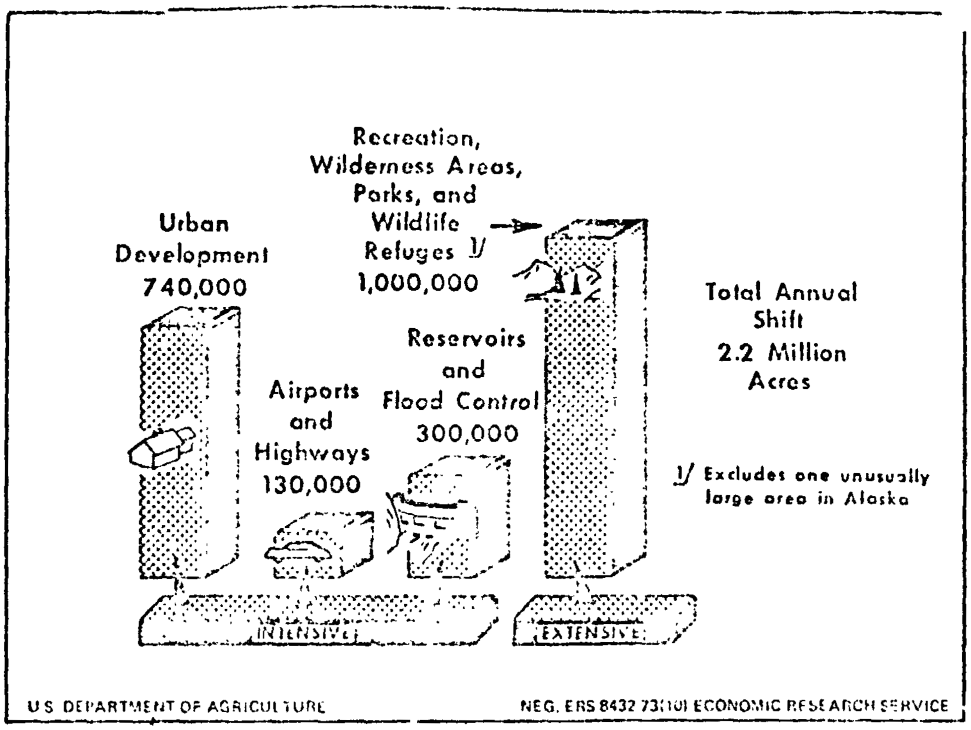

Figure 4 Rural Land Shifted Annually to Other Uses, Acres, 1959-69

2) If ERS provides worldwide statistics, additional potential U.S. benefits are $265-471 million for improved import-export decisions

3) If ERS provides worldwide statistics to the world community and the various regions and countries act upon such information in a timely fashion in production, distribution and import-export decisions (say by the year 2000), then benefits accrue to the world community of potentially up to $35,800 million for all crops.

Summary of Benefits:

Equal Capability;	$4.2	million
Increased Capability;	$106-$247	million
	($ 0 - 174	million)
New Capability;	$141-302	million
	($265-471	million)

1.5 Calendars

Accurate knowledge of crop calendars, as well as pest infestation cycles, can help assure optimal allocation of resources in the areas of planting, harvesting, and crop spraying. The use of large harvesting equipment, for example, which must travel throughout the midwestern grain belt by the end of the season, can be more efficiently scheduled if crop calendars for all the areas involved are known. Agricultural calendars are also an important input to remote-sensed crop identification efforts; knowledge of regional planting schedules, along with sequential imagery, is necessary for distinguishing between crops with similar spectral signatures.

Since an ERS system could provide up to continuous coverage of agricultural areas, it should be possible to develop crop calendars for any region at relatively low cost. Records of insect or disease infestations can also be produced and examined for possible cyclical tendencies. The benefits of such capabilities, however, are difficult to quantify and no efforts aimed at ERS crop calendar generation have been reported. Thus, there may be some potential for benefits in these areas, but substantial benefits do not appear to be realizable at this time.

1.6 Allocation

Benefits can result from the application of more timely and more accurate domestic and worldwide acreage, vigor and yield, and soil condition surveys in making decisions on planting and harvesting schedules. Benefits in the form of net gains to individuals or companies can be derived from better agricultural statistics obtained from a state-of-the-art ERS system.

The effects on production of agricultural crops were estimated using an ECON-derived model of the agriculture market.

Annual Benefits:

New Capability; ($15.4-118.8 million)

1.7 Conservation

An effective program of soil conservation yields benefits in reduced losses from wind and water erosion, and in the prevention of soil deterioration, with subsequent loss of productive capacity due to misuse of agricultural lands. Reductions in erosion also lead to improved regional water quality, since topsoil runoff, with consequent silt and chemical pollution, is reduced.

Remote sensing may provide more extensive and more timely data on soil conditions and on patterns of erosion. An accurate remote-sensed overview of an erosion area can allow more efficient and effective control measures, thus cutting losses. Losses may also be reduced if erosion were detected at an earlier stage; swifter preventative actions help prevent further damage.

The major contribution of an ERS system in reducing erosion and soil deterioration is its essentially 100% coverage, allowing identification and delineation of major erosion areas within a matter of months. Other areas, such as oven-dry fields, which might be susceptible to damage at any time, might also be identified, and losses, hopefully, averted.

The use of ERS imagery for timely identification of erosion and soil deterioration can yield benefits from reduced losses due to quicker ameliorative action.

Annual Benefits:

New capability; ($82.2 million)

1.8 Damage Prevention and Assessment

A state-of-the-art ERS system may contribute to many areas of damage prevention and assessment. These include the areas of crop disease, insect infestation, weed infestation and crop damage assessment. Both cost savings (equal capability) benefits as well as increased capability benefits are possible.

Present annual market value losses of agricultural crops due to disease, insects and weeds are estimated to be over $7.9 billion. Some of this loss can be avoided through more efficient allocation of fertilizers, pesticides and herbicides, based on more timely and more accurate information on the precise location and the extent of the infestation. Public benefits of reduced production losses due to these pests are estimated using an ECON-developed rough order-of-magnitude model.

Additional benefits of an ERS system result from cost savings to the Federal Crop Insurance Corporation (FCIC). At present the FCIC subcontracts this task to assessors. This process could easily make judicious use of an ERS system.

Annual Benefits:

Equal Capability; Damage Assessment $1.31 million

Increased Capability; Disease Prevention ($38-354 million)
Insect Prevention ($18-175 million)
Weed Prevention ($2.4-23.7 million)

Total hard; $1.31 million
Total soft; ($58.4-752.7 million)

1.9 Unique Event Recognition and Early Warning

Many types of unexpected phenomena occur which have a direct bearing on agricultural production, income, and prices. Meteorological events such as early frosts or floods, for example, can cause serious crop damage, especially if prompt protective action is not undertaken. The midwestern drought of the 1974 summer is another example of such damaging weather phenomena in which losses ranged up to 70% of the corn crop for some states.

Disease, weed, and insect infestations can also appear and spread quickly, inflicting major damage; there are many instances of outbreaks covering large areas before being detected. The gypsy moth, for example, was found in Michigan in late 1972; by the time a survey could be completed late in 1973 the moth had infested over 700,000 acres of forest and orchard lands.*

Other political or economic situations may arise from time to time, such as major trade opportunities, in which accurate information on agricultural conditions and expected production in the countries involved is of great importance if correct policy decisions are to be made.

More timely information on, or "early warning" of, events such as these yields benefits in three ways. First, where losses to crops or livestock are threatened, early warning means that preventative measures may be taken sooner, reducing damages. Second, where remote sensing can improve the quality of information available at a given time, decisions concerning preventative or remedial actions can be made more accurately, thus increasing their effectiveness and reducing losses further. Third, and most important, with more timely and accurate information commodity prices will move earlier and more precisely in response to more accurately anticipated events (rather than more violent ex-post-facto price movements); this effect leads to a multitude of changed decisions throughout U.S. and world agricultural transactions - of the commodity affected (say corn) - as well as its substitutes.

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* Statement of the Animal and Plant Health Inspection Service, in House Committee on Appropriations; Agriculture - Environmental and Consumer Protection Appropriations for 1975, Part 4, pp. 369-370.

Detailed RMF descriptions for this section examine the potential for benefits in some of the areas mentioned above. The area of crop losses is treated more thoroughly in Section 1.6; refer to RMF 1.6.2 for the method used to estimate benefits from reduced losses.

Benefits in these areas are realized periodically (about every two-to-four years) as different unique events occur. Benefits of $200-500 million accrue to the agriculture sector about once every two-to-four years from early warning of massive insect or disease infestations; another $200-500 million in benefits can be realized by the U.S. about once every two-to-four years from better information on world crop production, allowing better decision making on international trade opportunities (RMF 1.7.3 discusses the "Soviet Wheat Deal").

Annual Benefits;

New capability; Potential benefits of $400-1,000 million might occur every 2-4 years as unique events occur, but these are not counted in the totals shown in Table 1.

1.10 Research

Agricultural research activities, aimed at developing new crop strains, more effective fertilizers, and better pest control methods, are an important part of the effort to increase crop yields. Improved conservation measures to preserve soils and soil quality are also crucial if productive capacity is to be maintained and increased.

These and other research efforts are often first carried out in a controlled environment, where experimental conditions can be continuously monitored and adjusted. As research progresses, experiments may be expanded to a regional level, with a number of farms involved; in this case, far more extensive monitoring must be undertaken. Soil moisture, temperature, precipitation, and crop vigor must be measured frequently in both experimental and control areas; furthermore, in the case of conservation measures, an even larger area must be monitored so that the macro effects of the action can be appraised.

It is through these experimental monitoring and evaluation activities that an ERS system may contribute to agricultural research. The ERS synoptic view of very large areas not only provides simultaneous data on conditions within the entire experimental area, but also allows wide-area evaluation of the repercussions of, say, an erosion control experiment, or water diversion for a new irrigation project.

While the benefits of an ERS system, actively employed in agricultural research efforts, may be substantial, they can only be measured in two ways: as 1) cost savings in experimental monitoring of research efforts, and 2) reduced losses, since experiments may result in the availability of more effective control measures. Cost saving benefits are not likely to be very large, since the size of experiments is often limited by available project resources. Benefits from reduced losses, on the other hand, are substantial: these have been treated in depth in Section 1.6.

Annual Benefits:

Equal capability; Small, See RMF 1.1.3

New capability; See RMF 1.5.1

1.11 Administrative, Judicial and Legislative

Programs exist at the Federal and state levels which involve the enforcement of agricultural regulations, pertaining both to specific planting and plowdown procedures, and to acreage allotments for certain crops. RMF 1.9.1 describes in detail the California program for the control of pink bollworm in cotton, in which plowdown dates are specified and compliance must be checked to assure program success. RMF 1.9.2 describes the Agricultural Stabilization and Conservation Service (ASCS), USDA, program of crop acreage allotments, which involves ASCS acreage measurements and compliance checks.

An ERS system may be used to enforce regulations or allotments in these and other cases. In the California program, lands planted in cotton must be identified and mapped, and field conditions must be checked for these areas, later, to determine whether plowdown has taken place. It has been shown that ERTS can perform these functions for about 40% of the present ground survey costs, yielding an annual benefit of $2,000 for this small test site (80,000 acres) alone. The results indicate that, for larger areas, the cost savings may be closer to 50%. This cost ratio has not here been applied to any larger scale pest control efforts; commensurately larger benefits, however, can be expected from use of ERS enforcement of other government regulatory programs.

For the enforcement of ASCS acreage allotments, a model has been developed on the basis of man-hour allocations to acreage measurement and to compliance checks, by farm size. Total annual benefits from a changeover to ERTS acreage mensuration and compliance checks are estimated to be $15.8 million.

Annual Benefits:

Equal capability; ($15.8 million)

Increased capability; small

APPENDIX A:

Detailed Examination of Benefits by RMF

This appendix provides detailed documentation on benefit estimates for each Resource Management Function (RMF).

RMF No. 1.1.1

WORLDWIDE SURVEY OF AGRICULTURAL LANDS

Rationale for Benefits

Land and soil resource identification can yield substantial benefits to many countries where increased production is drastically needed*. Soil identification is the basis for suggesting introduction of new crop types which can increase the total supply of vital nutrients to developing countries; thus, benefits can be derived over time from increased land and soil survey capability. Nations could also identify the potential for and develop certain export crops, allowing national economics to grow according to their various comparative advantages, and yielding benefits in lower total costs of production.

Federal Government Activities and Responsibilities

There exists no present U.S. government activity except with respect to present use of ERTS-1 data by foreign researchers listed below.

Non-Federal Activities

The Food and Agriculture Organization of the United Nations, (FAO), conducts selected soil and land surveys around the world, and maintains facilities for instructing technicians of various nations in techniques for land and soil survey.

The United Nations at present has a requirement of 1:1,000,0000 scale mapping of world agricultural lands.

Functions of Remote Sensing

More extensive and more frequent surveying of resources is a major capability available with the use of remote sensed data. It is not expected that this function would replace existing surveys.

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* The interested reader may remember that in 1916-1918 Austria transported top soil ("black earth") from Ukrainia to Upper Austria by railroad to enrich local soils.

RMF No. 1.1.1

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Given the capability for extensive land and soil mapping, worldwide activity in land and soil monitoring programs should be at least an order of magnitude greater than U.S. activity since worldwide agricultural land is 10 times that of U.S. In FY 74 $8.0M was appropriated for a long term land inventory and monitoring program. Additionally the U.S. spends $25.5M (FY 75) annually for conducting soil surveys. The minimum gross benefit (increased capability) would be 10 times the $8.0M; the maximum would be 10 times the total present U.S. expenditures in this area. In so far as these benefits accrue outside the United States they are not counted as U.S. benefits in either the Summary (Volume I) or the Source Document (Volume II) of this report.

Current ERTS Activities

The following principle investigations are using ERTS-1 data for mapping of non-U.S. land and soil resources.

(1) Agriculture and Water Resource development in Bangladesh, GSFCID 1079A-OTO7D-C-DOOO

(2) Engineering Analysis of ERTS Data for Southeast Asian Agriculture. GSFC ID 1662A-UN01A-C-A000

(3) Assess the Value of ERTS Imagery in Accelerating Agricultural & Mineral Resource Development in Lesotho. GSFC ID 168JA-FOO3I-C-A000

Estimate of ERTS Economic Capabilities

Equal capability benefits of ERTS are essentially zero; the present level of activity in this area is so small as to be insignificant.

Annual increased capability benefits of ERTS range from a minimum gross expected benefit of $80M to a high of $335M. Mean expected gross benefits of ERTS are estimated to be $100M per year; however, these benefits accrue to the world community excluding the U.S.

RMF No. 1.1.1

Additional benefits accrue to the U.S. since it will be able to make better import/export decisions if it knows the world market more accurately. These benefits are counted in RMFs 1.2.2 and 1.4.1. These are new capability benefits.

Costs of obtaining the worldwide data are calculated based on a total worldwide acreage of 22.4 x 10^6 km^2, using a cost of ERS data, developed in Appendix D, of \$.073/km^2. The cost of annual worldwide surveys is \$1.64 million. Since these data are also obtained for worldwide agricultural surveys for the purpose of crop production forecasts, and discounted in RMF 1.2.2, their cost is not discounted here.

Annual Benefits:

Increased capability; (\$80-335 million*)
New capability; Accounted in RMF 1.2.2 and 1.4.1

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* Benefits accrue to world body (many countries) and are not counted in totals in Table 1.

RMF No. 1.1.2

THEMATIC MAPPING BY CROP TYPE AND SOIL TYPE

Rationale for Benefits

Agricultural thematic maps give detailed information on specific soil types or crop types; such maps serve as the primary vehicles for presenting survey results, and are valuable references for all persons and agencies who must work with regional information from these surveys. See RMF 1.1.3 for an explanation of ongoing soil survey programs.

Federal Government Activities and Responsibilities

The Soil Conservation Service, USDA, publishes thematic maps of soil types from data collected in its soil surveys (see RMF 1.1.3). $3.6 million was appropriated for this purpose in FY 1973.* Soil mapping and dissemination of information are carried out pursuant to the Act of April 27, 1935 (16 U.S.C. 590a-590f, and 42 U.S.C. 3272). There are no ongoing federal programs of thematic mapping by crop type.

The Function of Remote Sensing

Cost savings may result where remotely sensed data can be substituted for ground survey work. When the demand for information outstrips the resources of a data gathering agency, as is the case today with SCS, remotely sensed data can help meet the needs of all users on a much more rapid timetable, thus benefiting those users whose needs could not otherwise have been met due to manpower and resource constraints.

Economic and Technical Models for Estimting Benefits of Remote Sensed Data

Benefits are estimated directly as a percentage of government funding for thematic mapping activities. Figures on funding are based on an OMB breakdown of spending on all government mapping activities in FY 1973. Costs of obtaining data from remote sensing have been subtracted for the net benefits.

* Budget of the U.S. Government, Offic of Management and Budget (Government Printing Office, Washington, D.C., 1975).

RMF No. 1.1.2

Current ERTS Activities

ERTS principal investigators in this study area are:

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De Ingenieras Agronomos
Universidad Politécnica de Madrid
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Estimate of ERTS Economic Capabilities

Benefits are calculated on the assumption that the needs of all present thematic map users can be met with maps prepared from ERTS imagery. Thus, annual benefits (1973 dollars) realizable from application of ERTS remote sensed data to thematic mapping of soils are $3.5 million. This represents a mapping of 38,000,000 acres per year. Cost of equal coverage by ERTS as estimated in Appendix D is only $11,500 which is insignificant compared to the benefit. Net equal capability benefits are $3.5 million per year.

Annual Benefits:

Equal capability; ($3.5 million)

RMF No. 1.1.3

DOMESTIC SOIL SURVEYS

Rationale for Benefits

Soil surveys are of great value in identifying prime agricultural areas and assuring maximum efficiency by suggesting what particular crops or what other land uses are best for a given area. Uses of soil survey information include many government agencies and private planners, with needs ranging from maps of "soil associations" over large areas to comprehensive "reconnaisance" maps of smaller areas, as well as detailed surveys of soil characteristics such as moisture and temperature. The recent shift from a crop surplus situation to tight supplies and rising prices makes the search for additional croplands, as well as more efficient use of lands presently under cultivation, even more important.

Federal Government Activities and Responsibilities

The Soil Conservation Service (SCS), USDA, is charged with the responsibility, under the Rural Development Act of 1972, of carrying out a "land inventory and monitoring program" covering "the condition of land resources and identifying environmental degradation due to improper use of soil, water and related resources." The SCS also has an extensive on-going program of detailed and more general "reconnaissance" soil surveys. An estimated 90 such reports were sent to the Government Printing Office for publication in FY1974, covering an estimated 37 million acres of land. Approximately $25.5 M has been appropriated for these soil surveys in FY1975. The land inventory program was funded at the $8 M level for FY1974; no funding has yet been provided for FY1975.

SCS has set as a goal the mapping of a total of 2.3 billion acreas of land in the U.S. and Caribbean. As of June 30, 1973, 1.2 billion acres had been mapped. At the present rate, surveying and mapping necessary to meet this goal will not be finished until 1997; all results will be published by the year 2000*.

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* Hearings: Committee on Appropriation, House of Representatives Agriculture for FY1975, pt. 2, p. 387.

RMF No. 1.1.3

Functions of Remote Sensing

Remote sensed data may be used to reduce substantially the cost of preparing soil surveys and maps. Furthermore, remote sensing is well-suited to monitoring changes over time in the condition of land resources. Time savings in data collection should make resulting information available more quickly (i.e., before the year 2000) and help reduce losses from erosion and improper or unwise land use.

Larger scale benefits can be realized over time; the use of remote sensing will allow ultimate SCS survey goals to be met far earlier than is presently forecasted by the agency. Having this soil survey information earlier can allow demands for increased agricultural production to be met more quickly and more efficiently. Remote sensing will also be able to update existing maps.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

The use of remote sensed data can result in equal capability cost saving benefits. At present SCS subcontracts survey work to outside parties. Remotely sensed data could be obtained by substitute subcontract work. Cost saving benefits may be realized by ERS over present techniques, once ERS capabilities have been fully demonstrated.

In FY1974 SCS was funded to carry out a nationwide land inventory and monitoring program, with reports to be made every five years. Although funding for this program was not renewed for FY1975, a value can still be attached to remote sensed "land inventory" data of this type, which can be collected at essentially zero marginal cost if other agricultural land inventory tasks are also carried out by an ERS system.

In both these cases, the magnitude of benefits depends on the extent to which remote sensed data can be substituted for actual ground survey work; thus, yearly benefits are estimated as a function of the present annual funding for government programs in this area.

RMF No. 1.1.3

Current ERTS Activities

ERTS principal investigators working within this area are:

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A number of investigators have reported successful use of ERTS immagery in preparing soil maps of varying detail Baumgardner et. al.,* have prepared soil association maps from ERTS data which

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* M.F. Baumgardner, J.A. Henderson Jr., and LARS staff; Mapping Soils, Crops, and Rangelands by Machine Analysis of Multi-temporal ERTS-1 Data.

"compare well with existing soil association maps prepared by conventional means." Seevers et.al.* report that soil associations "can be identified on the basis of vegetation and topography," with sequential ERTS data. Enrico Mercanti,** of NASA's Goddard Space Flight Center, describes the results of Weston's work in South Dakota:

> F.C. Westin of South Dakota State University proved ERTS data to be a useful tool for the development of a land-value map of South Dakota. He did this by using ERTS bands 5 and 7 to help delineate the soil-association boundaries. After delineating major soil areas, more than 4800 land sale prices covering a period of 1967 to 1972 were associated with the soils areas and averaged. A legend explaining land-use, dominant slope, and soil materials of each delineated area was developed. The soil associations were then described as value areas and published on a 1:1,000,000 ERTS mosaic of South Dakota using band 7 for the base map.
>
> A line drawing of the soil-association value areas of South Dakota was then overlaid on the nearly orthographic ERTS mosaic. The resulting map, when keyed to the legend, describes the current agricultural land use and soils within each of the areas, and provides information on how buyers value the land in each of the areas. The map is intended for use by revenue officers to equalize land values in the state, by individual buyers and sellers of land and lending institutions as a reference source, as a reference map by those planning road routes, cable lines and pipelines, by conservationists in helping to keep inventories current, by agronomists needing up-to-date information on distribution patterns of crop growth, and by crop-yield forecasts to guide sampling strategy.

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* P.M. Seevers, J.V. Drew, D.T. Lewis, Evaluation of ERTS-1 Imagery in Mapping and Managing Soil and Range Resources in the Sand Hills Region of Nebraska.

** Enrico Mercanti, "Widening ERTS Applications," in Astronautics and Aeronautics, May 1974.

RMF No. 1.1.3

Elberson* has used ERTS imagery in mapping remote areas of Colombia. He reports that existing maps can be successfully extrapolated into unmapped areas on the basis of ERTS imagery supplemented by "sample strips of aerial photography." In conclusion he states that: "The resulting map shows sufficient detail to justify a publication scale of 1:500,000. It can be classified as a soil map which is in between exploratory and schematic. With repeated ERTS coverage and some field work it may be improved to a soil map which classifies in between exploratory and reconnaissance, [levels of detail, ed].

Since these maps are useful in the first stages of planning in remote undeveloped areas it is stressed that the application of conventional photointerpretation techniques (physiographic analysis) on ERTS imagery can yield significant practical results especially in the developing countries."

Estimate of ERTS Economic Capabilities

Potential benefits from ERTS mapping of soil boundaries are estimated at $33.5 million annually, the present level of funding for soil surveys combined with the FY1974 level of funding for "land inventory and monitoring." The findings of many investigators, especailly Weston and Elberson, indicate that information obtained from repeated ERTS passes can meet the requirements of land-use planners, agronomists, and government agencies who need soil survey information all the way down to the "reconnaisance" level of mapping.

Total cost of mapping the remaining 1.1 billion acres (1.72 million km^2) is $333,000, based on the calculation presented in Appendix D. This cost is insignificant compared to the benefit.

Annual Benefits:
Equal capability ($33.5 million)

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* G.W. Elberson, Interpretation of ERTS-MSS Images of a Savanna Area in Eastern Colombia. NASA SP-327, paper A13.

RMF No. 1.1.4

MONITOR AGRICULTURAL LAND USE CHANGE

Rationale for Benefits

The determination of patterns in land use change, through periodic mapping or surveying, yields a number of economic benefits. When inter-regional shifts in crop or livestock production are detected, for example, measures may be taken to minimize the impact of these changes in economic structure; new industry or government programs can be directed toward the affected areas. In another application, both government and private economic planners utilize land use change information to identify development needs in regions of increasing production. New demands for commodity transportation and processing, for example, can be anticipated and met as a result of this information.

Land use changes *from* (intensive) *agricultural* use *to other* uses are shown in Figure 4 for the 1959 to 1969 period. The average *annual* shift in land acreage from rural to other uses was 2.2 million acres.

Land use changes *within* agricultural sectors may either be shifts from cropping to grazing (or vice-versa), or from one crop to another. Monitoring of such changes has many useful benefits. Possibly unwise changes can be investigated and stopped; changes which might prove beneficial can be monitored and results reported. Benefits can result, then, from an ability to detect changes and monitor repercussions over time.

Federal Government Activities and Responsibilities

See RMF 1.1.3 for a description of the Soil Conservation Service (SCS) program of land inventory and monitoring.

The Function of Remote Sensing

Remotely sensed data can provide continuous information on land-use changes, allowing identification of trends and specific changes, and making possible timely remedial actions or further investigations, if necessary. Shifts in processing or transportation demands can also be anticipated earlier and needs met more quickly and efficiently.

RMF No. 1.1.4

Current ERTS Activities

ERTS principal investigators for this study area are:

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Numerous investigations have reported success in mapping land use patterns. Wilms* has used 1964 airphotos and 1972 ERTS imagery to confirm that substantial land use change from forest to agriculture has taken place in Montgomery County, Alabama. Wilson** et. al., have generated,

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* R.P. Wilms, Land Use Mapping and Change Detection Using ERTS Imagery in Montgomery County, Alabama NASA SP-327, p. 1625.

** A.D. Wilson, G.A. May, and G.W. Peterson, Mapping of Agricultural Land Use from ERTS-1 Digital Data, NASA SP-327, paper L22.

using band 5 for highway networks and band 7 for land forms, usable digital maps of broad land use at a scale of 1:24,000. Categories classified are cultivated land, forest land, and water; further sub-classifications have also been made but not yet confirmed.

Estimate of ERTS Economic Capabilities

The broad range of benefits described here overlaps with those in RMF's 1.1.3 (Soil Surveys), 1.8.1 (Monitor New Agricultural Practices) and 1.5.1 (Soil Conservation), as well as with the RMF area 4, Land Use. Thus, no additional benefit is claimed here.

Annual Benefits:

None, accounted for in RMFs 1.1.3,
1.5.1 and 1.8.1

RMF No. 1.1.5

REGIONAL PEST AND WEED SURVEYS

Rationale for Benefits

Early detection of crop pest and weed infestation can result in decreased damage and production losses, tantamount to higher yields. Accurate identification of infested areas should also yield cost savings due to a decrease in necessary application of pesticides (which also leads to an increase in environmental quality).

Federal Government Activities and Responsibilities

The Animal and Plant Health Services, USDA, is charged with overseeing and conducting pest and disease detection and control effects. As part of the "pest management" program, "insect scouts" conduct personal on-site inspections for the presence and extent of pest infestation. Control action decisions are then made on the spot; recommendations are given to growers as to the extent of pesticide spraying necessary.

For limited operation of this program, $1.5 million was allocated for FY 1973*; since data evaluation and recommendations for control actions are made on-site by scouts, by far the major portion of this amount represents expenditures for functions which could be assumed or supplemented by remote sensing.

Functions of Remote Sensing

Potentially, remote sensing may provide considerable cost savings, realized from a reduction of on-site inspections by pest scouts. More accurate delineation of the extent of infestation may be possible, allowing a reduction in amounts of pesticides necessary for pest control and eradication. There are indications that remote sensing may also detect and monitor insect breeding areas.

Current ERTS Activities

The following are on-going ERTS investigations pertaining to this RMF:

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* U.S. Senate, Committee on Appropriations, Agriculture-Environmental and Consumer Protection Appropriations, Congress, 2nd Session, GPO, 1972 pp. 332-335.

RMF No. 1.1.5

1. "Gypsy Moth Investigation" GSFC ID 1679A-AG01G-C-0000

2. "Study of Wheat, Phenology, Vigor, Pests, Diseases and Yield" GSFC ID 1569A-F001A-C-0000

3. ERTS Survey of a 500 km^2 Locust Breeding Site in Saudi Arabia demonstrated the feasibility of detecting potential locust breeding sites by satellite.

Estimate of ERTS Economic Capabilities

ERTS can provide significant increased capability benefits in the detection and monitoring of pest breeding areas and areas of infestation. Benefits of such data would accrue from their use in eradicating the pest and would result in increased yield. Such benefits would result from better allocation of pesticides and herbicides presently used in the agriculture sector. Additional cost saving benefits may result from reduced consumption of pesticides and herbicides. Benefits resulting from such increased yields have been accounted for in RMF 1.6.2.

Annual Benefits:

Increased capability benefit accounted for as part of RMF 1.6.2 and 1.6.3

RMF No. 1.2.1

DOMESTIC CROP ACREAGE AND YIELD MEASUREMENTS AND PRODUCTION FORECASTS

Rationale for Benefits

Estimates of crop acreage and yield, leading to forecasts of total production levels, are essential for efficient planning in all phases of production and distribution. Accurate forecasts permit more precise planning for planting, harvesting transportation and processing of commodities, can help identify potential shortages, and lead to earlier and less widely fluctuating price movements. Reliable final yield and acreage estimates provide the information necessary for optimal inventory holdings by processors, and allow better estimates of future demands for farm machinery and services. Crop types in need of intensive yield improvement or overall acreage increase might be pinpointed, and appropriate administrative actions taken. All in all, some 550 reports of these types are turned out yearly by the federal government alone related to acreage, yield and production of agricultural commodities.

The forecast of agricultural production is an activity of major importance in the management of natural resources. It is practiced in virtually all countries of the world. Reasons for the benefit of improved crop forecast accuracy are:

1. Inaccurate forecasts result in distorted and violent price movements which cause large private costs and costs to society.

2. Timely and accurate forecasts of surpluses or shortfalls allow governments and private operators to plan domestic and import/export policies and actions; e.g., increased output, reduced costs, remedial action against declining prices.

3. Accurate forecasts allow governments and private operators to optimize the utilization of existing storage, transportation, processing infra-structures and facilities.

RMF No. 1.2.1

Federal Government Activities and Responsibilities

The Statistical Reporting Service (SRS), USDA, is responsible for monthly crop reports under 7 USC 411a, and for detailed monthly information about the "condition and progress of the [cotton] crop", and the "probable number of bales which will be ginned" under 7 USC 475, 476. SRS state field offices are responsible for most data collection. Virtually all surveys are carried out by mail; a sample of farm operators are contacted and asked about both their own farms and agricultural conditions in their local areas. Increasing use of aircraft surveys is being made. Crop acreage, yield and production forecasts are generated from survey results, which have been adjusted statistically for percentage non-response to mailed survey torms. An estimated $26,096,000 has been appropriated for these activities in FY 1975.

The following is an SRS description of its sampling program:

> The Statistical Reporting Service has been moving toward a program of improved estimates through increased use of probability sampling since the mid-1950's. Previously, reliance for data collection was on the traditional mail questionnaire survey. But, changes in farming and marketing eroded this system.
>
> As farms specialized, became fewer in number, but often larger in operation, the mail survey method alone was not sufficient for the accurate estimates needed in agriculture. For example, not all farmers receive a questionnaire, and of those who did, not all respond. Also, the respondents may not be representative of the full group because of differences between their farms and others not in the sample.
>
> In 1951, a "bust" in the cotton estimate brought the problem to public attention. It led to a congressional investigation that identified the need for more modern forecasting procedures.
>
> The Statistical Reporting Service responded to the challenge and set up a research staff to develop and improve statistical techniques. A long-range program recommended probability sampling for enumerative

surveys and objective measurements of crop yields. The program was initiated on a pilot basis in 10 states in 1954 and gradually expanded to fully operational in 48 states in 1967.

Statistical theory provides a basis of selecting samples so that the chance, or probability, of each farm or farmer being in the sample can be computed. This offers two definite advantages: Since the probability sample represents a cross section of U.S. farms, the estimates are not biased as they may be when sampling by mail with no follow-up of those who don't respond; and probability sampling provides information for computing sampling errors. Thus, estimates can be made with a known degree of precision.

Probability sampling is applied to many estimating programs of the Statistical Reporting Service. The enumerative surveys conducted in June and December, two major data collections, and estimating efforts of the agency, are founded on the probability technique.

The sample for the June survey is about 0.6 of 1 percent of the total land area in the 48 states and includes about 17,000 area segments, and around 25,000 resident farm operators, including some 4,000 extremely large livestock and poultry farms.

Now to the point of using information from county agents. At one time in our program, we relied extensively on their subjective evaluation of the farm situation to help us form production estimates. But, this system will not suffice any more than the outmoded mail survey. We still consult them for their valuable and professional reading of conditions. In 1973, the Statistical Reporting Service and the Extension Service signed an agreement whereby county agents will help inform farmers of the crop and livestock estimating program and encourage their cooperation. We also count on the agents for data for the Weekly Weather Crop Bulletin published jointly by the Departments of Agriculture and Commerce. We also ask county agents to help recruit enumerators and crop reporters.

As to fuller use of county agents' time and talent in surveys, it would strain to the breaking point their already busy schedule. Field enumeration--both the personal interviews with farmers, and counts and measurements of crops as a gauge of yield--requires extensive specialized training and a great amount of time during the critical survey periods.

Our estimating record of recent years has substantiated the good judgment of implementing the probability sampling program. The estimates have held up well during a period of dynamic growth and change in agricultural production and marketing. The current surveys have been able to reflect what actually occurred in agriculture. For example, 1973's abnormal weather and economic conditions forced farmers to do many things they had not done before with their crop and livestock programs. Our estimates were subjected to heavy scrutiny by many analysts, and the confirming evidence has not refuted our published data.**

An analysis of the accuracy of annual crop forecasts by Gunnelson et al* concludes that the USDA tends to (1) underestimate crop size, (2) underestimate the size of changes in production from year-earlier levels and (3) undercompensate for errors in previous forecasts when developing revised crop production forecasts. Absolute forecasting errors are a function of the length of the forecasting period. Examples of average forecasting errors by month of forecast for various commodities are presented in Table 2 below. Reduction of this error leads to both private and social benefits.

Non-Federal Activities

Expenditures on agricultural statistics vary widely from state to state, largely as a result of different levels of agricultural activity. Table 3 gives total state funds appropriated for the collection and publication of all types of agricultural statistics.

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* Gunnelson, G. et al., "Analysis of the Accuracy of USDA Crop Forecasts" American Journal of Agricultural Economics, Vol. 54, No. 4, Part 1. November 1972: pp. 639-645.

** U.S. Congress, Appropriations Hearings - 1975, USDA-SRS.

Table 2 Size of Average Absolute Percentage Forecasting Error in USDA Annual Crop Forecasts by Commodity and Forecast Month, 1929-1970[a]

Commodity	Average Absolute Error by Forecast Month, Percent (Forecast of Annual Crop)								
	December	April	May	June	July	August	September	October	November
Barley					7.1	3.1	2.2		
Corn					9.2	5.9	4.0	2.8	2.0
Oats					4.9	2.9	2.4		
Potatoes						5.5	4.5	3.2	2.6
Soybeans						5.6[b]	5.1[c]	3.7[c]	2.9[c]
Spring Wheat					10.7	6.7	3.0	2.8	
Winter Wheat[d]	11.5	8.5	7.6	6.9	4.0	2.1			

[a] Forecasting error equals the absolute difference between the forecast and the December revised estimate expressed as a percentage of the December revised estimate.

[b] Percentages computed from data for 1944-1970.

[c] Percentages computed from data for 1940-1970.

[d] Error percentages for December winter wheat forecasts computed from data for 1942-1970. Error percentages for other winter wheat forecast months computed from 1929-1970 data.

Reference: Gunnelson, G., et al, "Analysis of the Accuracy of USDA Crop Forecasts" American Journal of Agricultural Economics, Vol. 54, No. 4, Part 1. November 1972: pp. 639-645.

Table 3 Funds Appropriated for Agricultural Statistics by the States

Fiscal Year	State Funds, $ millions
1973	4.2
1972	3.9
1971	3.5
1970	3.5
1969	3.1
1968	2.9

RMF No. 1.2.1

Functions of Remote Sensing

Use of remote sensing data can provide more timely and more accurate data on acreage and present state of the crop. *Timeliness* is obtained by eliminating the lag time between the gathering of data by farmers and the receipt of completed questionnaires by the USDA. Improved *accuracy* is obtained from increasing the sample size along with increased reliability of the data gathered.* Substitution of remote sensing methods

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* The reliability of the USDA's crop forecasting data base is questioned because of problems illustrated in the following House Appropriations Committee Hearings (FY'74 DOA Pt.1, Page 354):

"MR. SCHERLE. I have always been vitally concerned about the statistics and methods of reporting. As you admit, they have not been too accurate, sometimes you appear to throw a dart at a board and see what you come up with, even though we give additional money each year for betterment of the system.

"You say that you have sample methods. Why don't you take one State, Iowa, or Illinois--it doesn't make any difference--where your agriculture production is heavy and why don't you let the landgrant college in that particular State run the statistical reporting service for you for a quarter or 6 months or even a year? Why don't you use the county agents in every single county that travel that whole county day after day?

"I have farmed for 25 years and even to this date I don't know how you get your samples. When I get them in the mail I file them in a bucket and pay no attention to them. I am sure there are thousands that do that so there is no way you could get an accurate picture. If I keep more cows or heifers I am going to lie to you, so-and-so, as did my neighbor. We are not going to tell you the truth, and you know that, Doctor.

"MR. PAARLBERG. No, I don't know that.

"MR. SCHERLE. We want to throw you off base as far as you possibly can so you are coming up with figures which are rather long than short.

"MR. WHITTEN. What you are saying Dr. Paarlberg is that you know these factors, and how to allow for them?

"MR. PAARLBERG. That is precisely the point.

"MR. WHITTEN. That is the art of it? How big a tale they are going to tell you?

"MR. PAARLBERG. We have a correction factor we apply to gentlemen like Congressman Scherle."

probably will not result in substantive cost savings to the Federal Government since much of the existing surveying will probably not be curtailed. Crop reporters who now donate their services would continue their work and assist the remote sensing system by providing periodic "ground truth" data.

Improvements above and beyond USDA's existing information and forecasting base can come about in the following ways.

1. A *more accurate* crop forecast is made possible in any one month for which such forecasts now exist;

2. A *more timely* crop forecast with the same uncertainties (errors) as already provided, say in June as against July; and

3. *More frequent* forecasts, e.g., weekly instead of only monthly, or for more months than are now provided for.

Improvements in forecast accuracy resulting from improved statistical information are shown in Figures 5 and 6.

Present USDA crop production estimates are arrived at as the product of two components: acreage and yield per acre. The function of an ERS System in providing data for production forecasts is as follows:*

<u>Acreage Component</u>. Approximately one-half of the uncertainty of the SRS forecast of U.S. wheat production is contributed by the estimation of the acreage component. Thus, even if remote sensing could improve only the acreage estimates, a significant improvement in the production forecast would result.

In the past decades very extensive changes have taken place in (1) total cropland acreage and (2) type of crops grown in the United States. The most dramatic of these has been the spectacular rise of soybean production in the past 10 years, a crop with little yield variation, and total production mostly determined by acreage.

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* Wood, D.B., "The Use of ERTS for Crop Production Forecasts," GSFL Task Force on Agriculture, Final Report August 1974.

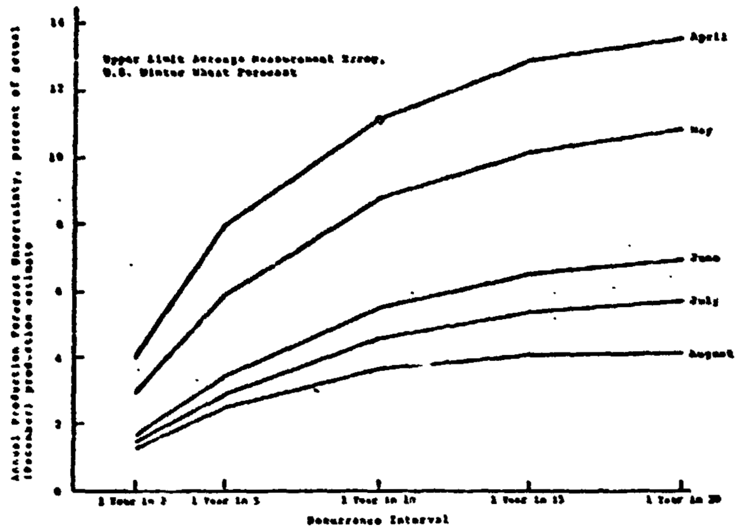

Figure 5 Contribution of Acreage Measurement to Improvement of Crop Forecast Accuracy: by Recurrence Interval

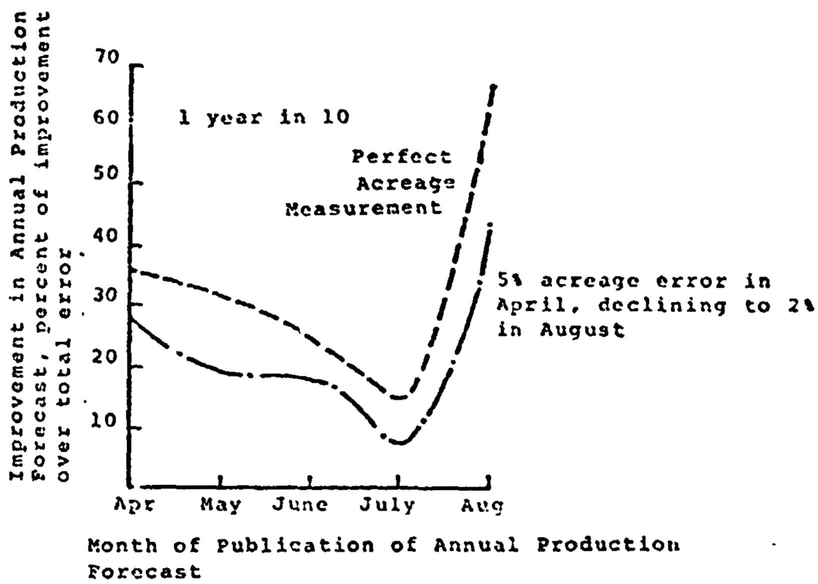

Figure 6 Contribution of Acreage Measurement to Improvement of Crop Forecast Accuracy: by Month of Publication

Aside from soybeans, similar substructural changes in cropland acreage occurred in the United States even in times of "supply controlled" agriculture policies of the 1940s to the mid 1960's. *Increases* and *decreases* in cropland acreage between 1944 and 1964 are shown in Figure 3. Each dot in Figure 3 stands for a 10,000 (ten thousand) acre change in cropland. Significant decreases in cropland acreage occurred in the East, Southeast and South; increases in cropland acreage occurred in much more concentrated form in the Midwest, Northwest and West. The 1944 to 1964 changes have been substantial. Since 1964, and particularly in the past few years and years to come, with a return to an open market policy in U.S. agriculture and unusually fluctuating world prices these dynamic changes can but only increase.

The year-by-year and month-by-month monitoring of these changes, and the resulting changes in food supply, are one key ERS capability. The value of knowing these changes more timely, and more accurately--in the context of U.S. crop production forecasts--is the topic of the two in-depth ECON case studies in Agriculture (Note that Figure 3, drawn in 1969, only includes data up to 1964, a five year lag; Figure 4 (shown earlier) drawn in 1973 includes data up to 1969, or 4 year lag).

Measurement of acreage requires two capabilities:

1. Identification, i.e., determination of which fields bear which crops.

2. Mensuration, i.e., the measurement of the aggregate area of all the fields bearing the selected crop.

Both these functions are interrelated, since one cannot measure what is not identified. In an operational ERS system the mensuration function would be separate from the identification, or discrimination function.

<u>The Measurement of the Acreage Component, USDA Technique</u>. Uncertainties in total crop acreage are caused by the fact that it is obviously too laborious and costly to measure directly the entire crop-bearing area. Thus, acreage is estimated by sampling.

RMF No. 1.2.1

Mail replies from farmers provide a valuable data base. The acreage estimates from this source are supplemented by "exact" measurement of approximately 17,000 farm samples. This is accomplished twice yearly during the enumerative surveys. The enumerators--of which there are approximately 1,500 in the U.S.--accurately mensurate from aerial photography (scale 1:24,000) the selected sample fields. They mensurate total field area, and the fraction of total area devoted to crops (deducting pathways, fallow areas, canals, groves, and other unproductive or untilled areas). Mensuration accuracies achieved on the enumerated sample fields are of the order of 1/2%.

The total area which is exactly enumerated is approximately 0.6% of the U.S. crop growing area.

The enumerated sample is extrapolated to the total acreage by taking into account known characteristics of the field population and known historical trends. The underlying hypothesis is that the sample is a reasonably good representation of the whole, so that changes observed in the sample are reasonably accurate indicators of the variations of the whole.

Uncertainties in total wheat acreage are caused by:

1. The fact that total acreage is not mensurated, but estimated from limited sampling: Statistical Sources, e.g.,

   a. Inaccuracies in measuring the sample.

   b. Inaccuracies in extrapolating the sample to the whole.

2. Changes due to external factors: "RandOmness" of Nature and Prices, e.g.,

   a. Natural phenomena (drought, hail, winter kill, disease...).

   b. Economic reasons (plow under, or selective harvesting, if price is too low: late supplementary planting, if price is high...).

These "external" changes cause the harvested acreage to differ from the planted acreage.

Remote sensing techniques can increase the accuracy of total acreage measurement by providing:

1. Significantly increased sample size, which would reduce the sampling error.

2. More frequent sampling, which would keep track of acreage changes as they occur, and reduce the uncertainty of "external" changes.

More accurate measurements of acreage alone would lead to a significant improvement in forecast accuracy.

As the season advances from April through August, forecast accuracies generally improve (there exists an anomaly between July and August), see Figure 1.2.1-2, thus the maximum allowable acreage error diminishes. This requirement implies that the remote sensing system must be designed so accuracy is improved with increasing number of temporal samplings.

As the recurrence interval increases, one deals with increasingly exceptional years. One would thus expect the maximum allowable error to increase with recurrence interval.

Pure Mensuration. By "pure" mensuration is meant the capability to determine areas of fields of the same crop type or content. All pixels* of an ERS "picture" that are completely inside or fully outside the field in question can be unambiguously recognized. The contours or borders will provide a signal that is of mixed identity between the field in question and the surrounding fields. The uncertainty in border definition is what causes the mensuration error. The key to accuracy is to design the mensuration algorithm so as to make the error symmetric so that one field will be measured in excess, the other in deficit, with the net result that the errors will tend to compensate statistically.

For example, an ERTS-1 pixel covers about one acre of the Earth's surface. In general, any field will be edged with "boundary pixels" which contain mixed information from that

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* A pixel, or picture element, is the smallest resolution element.

field and its neighbor (e.g., the "grey" pixels described above). These boundary pixels can, at least in theory, be subdivided into the fractional acre covered in the object field and in the neighboring fields. The degree to which this can be done depends upon the contrast (i.e., radiance difference) between the fields and the length of the boundary.

Note that a relatively small area sample is sufficient to achieve high accuracies.

The error can be reduced further by exploiting the radiance levels. For purposes of exposition, assume that a "white" field borders on a "black" field. Note that as the pixel penetrates the black field its radiance changes from white through shades of grey to black. Depending upon how many grey levels can be separated, the effective pixel size can be made smaller than the pixel itself--yielding greater accuracy.

The number of detectable grey levels principally depend upon:

1. The dynamic range of the sensor.
2. The contrast ratio between the target being viewed and its immediate surroundings.
3. The reflected albedo from the scene.

For water, small values of contrast ratios are achievable. Realistic contrast ratios of agricultural fields vary from 1.2 to 1.5. With present ERTS sensors, this means a maximum of approximately 10 to 15 grey levels.

The theoretical "pure" mensuration was approached in several ERTS experiments aimed at mensurating areas of water, such as lakes. The high contrast between water and most of its surroundings approaches the "black and white" case of pure mensuration. Correlation of the ERTS experimental results indicates that: (1) there is a functional dependence between mensuration error accuracy and square root of the mensurated area; and (2) sophisticated "sub-pixel processing" can presently, in some cases, yield "equivalent pixel" size reductions of approximately 10:1 ($k \simeq 0.1$), where k is the ratio of smallest effective area mensuration to pixel size.

Whereas situations of "pure mensuration" may seldom occur, nevertheless the concept is most important in guiding the design of any large area operational crop inventory and/or forecast system.

Crop Identification. Identification relies upon the spectral signature, i.e., upon the different amounts of the sun's energy reflected by each crop.

Each crop, and each element of background (soil, roads, artifacts,...) reflects differently at different wavelengths. The eye senses these differences as colors and shadings; automatic sensors, as differences in wavelengths and light intensities.

Crops and background objects do not possess unique, exactly constant signatures. Signatures vary from field to field of the same crop, as functions of stage of growth, moisture, environmental conditions, etc. In some cases, even differences among diverse crops are small. To date, insufficient data have been collected *in situ* to adequately assess the similarities of the same and different crops.

Identification must rely therefore upon statistical techniques. The basic spectrum of a crop, taken so as to be free from background, atmospheric and environmental interferences, is known as the "pure" spectrum.

Error Balancing -- Crop Inventory Vs. Land Use. It has been noted that, in pure mensuration, the percentage acreage error on a single field is relatively large: but, that it can be reduced *ad libitum* by increasing the number of fields mensurated. This applies to all situations where the errors are random, i.e., where excesses are as likely as deficits. This is the sampling technique employed currently by USDA.

The key to successful acreage measurement is to design the system so that the random-error-compensating techniques apply to identification.

The identification technique currently most employed is oriented to land use, i.e., the delineation of the content of each segment of land. For example, determining whether a particular tract bears wheat, as distinct from a neighboring tract employed as pasture.

In crop inventory and forecasting, identification of each field is not of interest, but rather precise estimation of the total crop by crop acreage of a county, crop district, region or nation. It is thus possible to tolerate individual misclassifications, provided they are random and tend to wash out over a sufficiently large aggregate of fields.

Yield Component. The other error-producing measurement component of crop production forecasts is the yield. SRS performs yield estimates based on grower's evaluations and from a relatively small number of "objective yield" determinations performed in the field. For discussion, yield is subdivided into two subcomponents: the crop condition observed at a specific time, and the extrapolation of that condition through growth cycle to yield via growth model. Since factors influencing growth are primarily related to meteorological phenomena, growth models have been labeled "agromet" models.

Crop Condition. The crop condition can be considered as an "initial condition" or "boundary value" to an agromet growth model. As in the case of discrimination, of interest is the measurement of crop condition, or vigor, from the spectral signature data. Here again, dependence upon prior knowledge of cultural practices and of the phenological development of wheat is required.

Growth Model. The growth of any crop depends upon several environmental conditions: soil, rain, sun, wind, fertilizer, irrigation, disease, weather damage (e.g., hail or winter-kill), and so forth. Ideally, one would like a model of these phenomena from which, given the initial crop condition and the expected natural and man-made inputs, yield could be predicted.

The function of ERS would be to provide crop condition data which is totally unavailable (except for qualitative statements by farmers) and possibly better forecasts of weather conditions during the growth cycle.

Economic and Technical Models for Estimating Benefits

In the ECON case study on distribution effects of improved ERS information (Part II of this volume) an in-depth and well founded theory of the benefits from statistical measurement and reporting of crop forecasts is developed. We then applied that set of analyses to two specific crops, namely wheat, and soybeans for U.S. domestic distribution and consumption. However, to do this accurately for each crop and for all purposes is a time consuming and costly effort. For purposes of rough order of magnitude (ROM) estimates of these benefits to all crops we use a very simple model based on the work of Hayami and Peterson.* This model provides proportional benefits to other crops relative to wheat and soybeans. Consequently rough-order-of-magnitude benefits of ERS satellite information, sufficient in an overview exercise are added to the case study.

Hayami and Peterson point out that under the assumption of rational profit and utility maximization behavior by producers, marketing firms and consumers, a sampling error in statistical reporting of the production or the stock of commodities can be expected to lead to a net decrease in social value. Erroneous information causes producers to make erroneous production decisions and also distort optimal inventory carryovers. Hence, marginal improvements in the accuracy of these statistics reduces the social cost of misinformation, which is therefore net social welfare.

By making the further assumption that production cannot be altered significantly in response to output predictions, but where the inventory holders are able to adjust stocks, Hayami and Peterson sketch out a theoretical framework for estimating benefits of improved statistical information. The above assumptions are valid in the area of agricultural crops in that once the crops are planted, it is usually not profitable for producers to significantly expand or contract the output. On the other hand, it is relatively easy and inexpensive to store the commodities. In this case any market supply adjustment is possible mainly through adjustments in inventory.

Losses to the public, in general, due to errors in production forecasts arise because of distortions from the optimum consumption pattern of the products. Because products of this type are produced during a relatively short period of time within the year, their consumption patterns depend very much on the inventory policy of marketing firms. Expectations of a small crop in the forthcoming period leads to higher prices and reduced inventory depletion during the current

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* Hayami, Y., Peterson, W., "Social Returns to Public Information Services: Statistical Reporting of U.S. Farm Commodities", American Economic Review, March 1972, p. 120.

period. If production responses to a price change can be considered to be perfectly inelastic during the production period, then if the crop yield turns out to be greater than expected, the inventory surplus that will be created in the forthcoming period will require a higher inventory depletion rate through lower prices. The economic losses to the public as a result of such production forecast errors are discussed below and are referred to as the ECON Rough Order of Magnitude Models (ECON ROM Models) and are developed in Appendix E. For an in-depth ERS information evaluation the reader is, however, referred to the ECON wheat distribution case study of this report (Part II of this volume).

Current ERTS Activities

The following are current ERTS investigations in the area of domestic crop acreage and yield measurements.

1. "Purdue/LARSYS Crop and Soil Characterization and Mapping Using ERTS CCTS"
   GSFC ID 1050A-UN01D-C-A000

2. "Regional Agriculture Surveys Using ERTS Data"
   GSFC ID 1277A-UN01A-C-A000

3. "USDA/MSC Six County Agricultural Study"
   GSFC ID 1703A-AG-X000

4. "Remote Sensing in Iowa Agriculture"
   GSFC ID 1249A-UN01A-C-A000

5. "Crop Identification & Acreage Measurement Utilizing ERTS Imagery" GSFC ID 1013A-AG01A-C-A000

6. "Obtain County Agricultural Statistics for Selected Counties and to Map Agricultural Phenomena" GSFC ID 1060D-UN01A-C-A000

Comparison of ERTS and Aircraft Results. A tabulation of most available aircraft and ERTS Remote Sensing results discloses:

1. Sampling (inventory) mode results, even without deliberate optimization, cluster nicely around the 100% mark.

2. From the relatively limited comparative sampling performed, small grains as a class appears to promise better identification than wheat by itself.

3. The results are particularly encouraging because no sampling (inventory) mode optimization was attempted. Further, the corrections for external distorting causes: haze, path radiance, sun angle, scan angle, where performed only sporadically. In many cases, methodic calibration of the instrumentation was less than thorough. Figures 5 and 6 show the actual and estimated capabilities of an ERS System in measuring acreage as reported by the Task Force on Agricultural Forecasting.

Comparisons of the accuracies predicted by theory with the results obtained by ERTS investigators in measuring crop acreage have found the following:

1. That the error diminishes as the area increases;

2. The use of special border pixel algorithms significantly improves the acreage measurement accuracy (Thompson);

3. Finally, that the errors are encouragingly small, in spite of the fact that the experiments were land-use oriented, and thus did not attempt threshold optimization for the inventory mode.

In this section four ERTS investigations of particular pertinence to the issue of area measurement are discussed in detail.

Thompson Investigation

"Crop Species Recognition and Mensuration in the Sacramento Valley."

Description. Among other investigations, the area of seven rice fields were measured using a recognition algorithm and another algorithm which proportions boundary pixels between the fields on either side. Away from the boundaries, rice was well distinguished from other crops, as all 30 rice fields in the study were recognized as rice. The data for the seven selected fields are given in columns 1-4 in Table 4.

Interpretation. A statistical interpretation of these data is shown in columns 5-8 of Table 4. The recognition estimate finds 84.4% of the rice area. This corresponds closely with the expected error if all non-boundary pixels are correctly recognized, $\varepsilon = 2\,r/\sqrt{A}$, where r is the resolution, and A is the average field area. For ERTS, $r^2 = 1.1$ acres, and for $A = 1221/7 - 174$ acres, $\varepsilon = 0.16$. Then $\hat{A}/A = 1 - \varepsilon = 83\%$ would be the expected correct recognition.

With the proportional determination, or mixture method, an error of (.3 - 1.9)% was made, so that the residual bias was dominated by the internal statistical error. This demonstrates that the residual error was decreased by using the mixture method from 16% to 1.9%. The boundary pixels were proportioned correctly to better than (1.9/16) x 100 = 12%.

If we write the estimated acreage A as $\hat{A}/A = 1 \pm 2k\,r/\sqrt{A}$, then for this example, $k < 0.12$.

In general, k will be dependent on field shape, and on the radiometric noise compared to the cluster separation in color hyperspace. Since radiometric noise of reflectance variations within a field may be treated as random errors, if the errors of omission and commission are balanced, then we may expect a residual bias level k of less than n/D where n is the color-space noise level and D is the cluster separation.

Malila and Nalepka Investigation

"Atmospheric Effects in ERTS-1 Data, and Advanced Information Extraction Techniques"

Description. ERTS-1 data were used to estimate the area of 20 small lakes in southwest Michigan. Analysis was done with the recognition processing and proportion estimation processing as in the Thompson study. By recognition processing, 11 of the 20 lakes were found with a total estimated area of 451,900 m^2 compared to the "ground data" of 1,004,200 m^2, that is 45.9% of the area. By proportion estimation, 19 of the 20 lakes were found, with an area of 965,800 m^2, that is 96.1% of the area. The "ground data" was an aerial photograph, from

Table 4 Thompson Study on Rice

Rice Field	Ground Measured Acreage	Recognition Estimate	Recognition + Commixed	Col 3 / Col 2	Col 4 / Col 2	Δ Col 6 -1	Δ^2
1	150	119	144	.794	.961	-.039	.00152
2	212	174	205	.822	.968	-.032	.00102
3	106	71	95	.670	.896	-.104	.0108
4	159	130	163	.819	1.025	.025	.00062
5	176	149	179	.847	1. 17	.017	.00029
6	194	173	196	.893	1.010	.010	.00010
7	224	214	236	.955	1.052	.052	.00270
Total	1221	1030	1218				
Average	174			.844	.997	-.003	.01705

Measured Error of Average = $\bar{\Delta}$ = -.003
Number of Samples = N = 7

$N\sigma^2 = \Delta^2 - N\bar{\Delta}^2 = .017 - 7 \times .003^2 = .017$

Therefore Standard Deviation of Sample = σ = .049
Standard Deviation of Mean = $\sigma/\sqrt{N}$ = .019

Error of Average = .003 $\pm$ .019

Source: Wood, D.B., "The Use of ERTS for Crop Production Forecasts." GSFC Task Force on Agriculture, Fiscal Report, August 1974.

which the lake areas could be easily measured. The error was reduced from 55% to 3.9%, an improvement factor k = .07. However, some points containing small percentages of water were eliminated by inspection, and it is not stated how many, or what area was removed. The mean lake area was 18 acres.

Interpretation. To determine whether the elimination of the pixels with small water percentages was correct, the removal proportion criterion would need to be set on training data and the area estimated on test data.

The poor recognition of 45% may be due to the irregular shape of lakes, so that an unusually large fraction of pixels were at the borders. For square lakes of average area 18 acres, 52% of pure pixels should be recognized.

The standard deviation of the error cannot be estimated from the published data since the data for the individual lakes is not given.

Morain Investigation

"Kansas Environmental and Resource Study - A Great Plains Model"

Description. ERTS-1 images were photo-interpreted, using data taken in the fall of 1972 over southwest Kansas, to distinguish wheat from other crops. In late September, winter wheat is being planted and only the winter wheat fields are newly plowed at that time. In November, wheat is the only green crop. Further observations were made in March, to detect underplowing, and at harvest. In the fall, wheat can be well distinguished from other crops and land use in MSS-5 band images.

An ERTS estimate of acreage was prepared in March 1973, and compared with the SRS May '73, August '73 and February '74 estimates for 10 counties in southwest Kansas. The total for the 10 counties from ERTS was less than the SRS February '74 by (4.7 ± 4.5%); the standard deviation was calculated from the individual county variances.

In addition, Morain classified 377 fields in Finney County, all 80 acres or larger, with average size 145 acres, 89% of fields were correctly classified, and 99% of the area was estimated. The method of obtaining ground data was not stated. SRS statistical data would not be accurate to 1% over one county because of sampling errors. These results are not being used until this problem is clarified.

Von Steen Investigation

"Crop Identification and Acreage Measurement Utilizing ERTS Imagery"

Description. Several agricultural test areas were selected including one in Missouri, in which cotton and soybeans were the major crops. Advantageous dates were not selected, but an analysis was performed using spectral bands from three dates and unequal prior probabilities. Using training fields as test fields, an area estimate accuracy of 906 927 samples (2.3% error) for cotton, and 866/852 samples, (1.6 error) for soybeans was obtained. The average field size was of order 20 acres for cotton and soybeans (Feb. 19, 1974 report). Individual sample identification errors were 20.3% and 28.1% for cotton and soybeans, so that the errors were balanced out in the area estimate with improvement factors k = .11 and .06 respectively. Errors were larger in the other crops (e.g., wheat) because of their relatively small areas and remaining low discrimination.

Interpretation. The use of three times for classification may be regarded for mensuration purposes as a somewhat higher discrimination scene than one time. The use of training fields as test fields does not invalidate the result if the training is applied to identify a cluster and not to size its boundaries, and if the identification is locked on to the nearest cluster centroid in an operational system. For this locking on to work, the cluster must have a significant number of members, i.e., the crop must have several pixels in the scene.

Unequal prior probabilities were used, presumably to select the cluster borders in color space, and this was found to improve the accuracy. That is the cluster selection criterion is weighted by the expected importance of each crop in the area. (This goes some of the way to an objective scene-dependent scheme to balance the errors of omission and commission.)

KMF No. 1.2.1

Only one ERTS investigator (Kanemasu) has specifically addressed the determination of wheat yield from ERTS data. The following is a critique as presented in "The Use of ERTS for Crop Production Forecasts", D. B. Wood, GSFC, July, 1974.

Kanemasu Investigation

"Kansas Environmental and Resource Study: A Great Plains Model"

Wheat: Its Water Use, Production and Disease Detection and Prediction. February 5, 1974. Completion Report No. 2263-3.

Abstract. In this report are discussed (1) the effects of wheat disease on water use and yield, and (2) the use of ERTS-1 imagery in the evaluation of wheat growth and in the detection of disease severity.

Leaf area index was linearly correlated with ratios MSS4:MSS5 and MSS5:MSS6. In an area of severe wheat streak mosaic virus-infected fields, correlations of ERTS-1 digital counts with wheat yields and disease severity were significant at the 5% level for MSS bands 4 and 5 and band ratios of 4/6 and 4/7.

Data collection platforms were used to gather meteorological data for the early prediction of rust severity and economic loss.

Critique. The Kanemasu work covers many facets of crop development, including remote and in situ measurements. Three facets of his work are of particular value for assessing crop production forecasting by remote sensing. His soil moisture work is not included in this critique.

1. Kanemasu established an important correlation between leaf area index (LAI) and remotely-sensed data. The LAI is a measure of the total leaf area of the plant.

Data collection extended from September 1972 (at planting) through July 1973 (after harvest), covered by six (6) ERTS passes. Two fields were studied in Finney County, Kansas; one irrigated and one dryland. The irrigated and dryland fields fall on the same line, the only difference being greater leaf area and hence larger MSS4/MSS5 for the irrigated field. The leaf area index for grain crops increases as the plant develops, reaching a maximum about six weeks before full ripening, then decreases as the grain ripens. Hence, the correlation of LAI with remotely-sensed parameters has important implications on our ability to sense, from space, the vigor and maturity of wheat and other crops.

2. As part of his analysis, Kanemasu collected data from a 450-square-mile area of Finney and Gray counties, Kansas, which contained both health and wheat streak mosiac virus-infected wheat fields. In each of 54 fields, random samples of wheat were harvested and objective yield determined. The results were divided into four yield groups:

   A : 13.8 - 20.0 bu/acre (mean 17.4)

   B : 20.1 - 25.0 bu/acre (mean 23.0)

   C : 25.1 - 30.0 bu/acre (mean 27.8)

   D : 30.1 - 41.6 bu/acre (mean 36.4)

   ERTS-1 MSS data were collected from these fields on four different dates:

   March 20, 1973; May 13, 1973; May 31, 1973; and June 18, 1973.

   Kanemasu determined that on May 31 the MSS4/MSS5 ratio correlated with yield with a correlation coefficient of 0.34, significant to the 5% level. This evidence is not terribly strong, but it is indicative that it may be possible to predict yield via remotely-sensed data (see analysis below).

Any direct correlation between ERTS data and wheat disease is not, at this time, convincing.

3. Most of the other results pertain to in situ plant measurements. Of particular interest are field measurements of wheat, sorghum, soybeans and soil, correlated with wavelength, soil mositure, and sun angle. This work shows that a reflective ratio (545- to 655-nm) provides good benchmarks of plant growth; and is not affected by sun angle. The ratio does not appear to discriminate between species, but should be a valuable parameter when used with other recognition processes.

Analysis of Kanemasu Data. Further analysis of the Kanemasu study by the GSFC Task Force on Agriculture concluded that:*

> From the laboratory and theoretical work that have been done on plant canopy reflectance, there is considerable theoretical justification to expect LAI, hence plant vigor and possibly yield, to be mostly manifested in the infra-red. The data presented by Kanemasu indicates that yield apparently can be predicted from ERTS observations approximately four to six weeks before harvest. Also wheat harvest stubble shows a significant increase in radiance in all bands. The evidence is that stubble can be distinguished from ripe wheat primarily on the basis of its exceptionally high reflectivity. Therefore, harvested acreage can be measured.

Estimate of ERTS Economic Capabilities

1) Cost saving benefits to state agriculture departments from their reliance on ERS-derived statistics in place of their independent agricultural statistics gathering activities (see Table 3).

2) The ECON ROM Model that considers an exponential demand curve.

3) Reduction in acreage estimated error by 1.5 and 2.0 percent

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* Wood, D. F., "The Use of ERTS for Crop Production Forecasts," GSFC Task Force on Agriculture, Final Report, August 1974.

4) Improvement in crop vigor data resulting in a 0.5% error improvement

5) A combined improvement in acreage and vigor estimates resulting in a reduction of average growing season forecasting errors of 2.0%

Table 5 lists estimated annual ROM economic benefits for the twelve (12) most valued domestic crops. Resulting annual ROM economic benefits of improved production forecasts for domestic crops (distribution effects) are estimated to be at least $247 million/year (based on achieving a 1.5% error reduction) to $407 million/year (based on achieving a combined 2.0% reduction in production estimate errors through improved acreage and crop vigor estimates). The 1.5% error reduction involves demonstrated improvements in acreage estimates. The 2.0% reduction adds an expected .5% improvement in yield estimates.

Table 5 Estimated Annual ROM Economic Benefits for the Twelve Most Valued Domestic Crops

Crop	Mean Total Forecast Error (%)	Domestic 1972 Crop Value $ Billions	RGM Price-Demand Elasticity	ROM Benefits* from Reduction in Production Forecast Errors by 1.5% $ millions	2.0% $ millions
Corn	4.7	7.017	0.1	(85.4)	(106.4)
Soybeans	4.3	4.451	**	71	150
Hay	--	3.662	0.1	--	--
Sugarbeets	2.7	0.456	0.08	(3.4)	(3.9)
Wheat	6.2	2.575	**	35	83
Cotton	4.6	1.743	0.1	(20.7)	(25.7)
Tobacco	2.0	1.442	0.5	(1.1)	(.1)
Citrus	--	0.857	0.3	--	--
Sorghum	4.8	1.041	0.1	(13.0)	(16.2)
Potatoes	4.0	0.751	0.1	(7.5)	(9.2)
Rice	2.9	0.562	0.1	(3.6)	(4.3)
Peanuts	4.0	0.477	0.2	(2.3)	(2.9)
Oats	3.4	0.471	0.1	(3.9)	(4.6)
Total Benefits				106 (140.8)	233 hard (174.3) soft

* Estimated based on ECON ROM Model except for soybeans and wheat.

**Soybeans and wheat estimated from ECON integrated market model, Volume III, Part III, Table V.4, lower bound.

RMF No. 1.2.1

Benefits derived from the integrated model, Volume III, Part III, for wheat and soybeans only are in the range $106-549 million. The lower limit is substantiated by the distribution model for wheat only, Volume III, Part II, as discussed in Volume I, Chapter 3 and Volume II, Chapter 3. The benefits attributed to this RMF are as follows.

Annual Benefits:

Equal Capability;	$4.2	million
Increased Capability;	$106-247 ($ 0 -174	million** plus million)***
New Capability;	$141-302	million**

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* These benefits derive from cost savings to state agriculture statistical reporting services, see Table 3.

** Measured benefits derive as follows: The sum of increased capability and new capability benefits ($247-549 million) are substantiated by the two case studies in agriculture for wheat and soybeans only (Volume III, Parts II and III) and by the additional work presented in the RMF for other major crops. The increased capability lower bound ($106 million) derives from the lower bound of benefits for wheat and soybeans alone. The new capability lower bound ($141 million) derives from column five of Table 5. The sum of these benefits ($247 million) can be taken as a firm lower bound due to the extreme conservatism used to derive the lower bounds for wheat and soybeans only. This is a likely lower bound for those two crops alone and could certainly be achieved given potential related benefits for other major crops. The total upper bound of benefits ($247 + 302 million) corresponds to the upper bound of benefits for wheat and soybeans only. The division of benefits between increased capability and new capability is largely subjective. However, the increased capability part is due mainly to distribution effects with the upper limit of $247 million in measured benefits equal to the upper bound of distribution effects for wheat only (see Table 3.3, Volume I).

*** An additional soft benefit of up to $174 million derives from the potential benefits for other major crops assuming a larger error reduction (2% instead of 1.5% - see column six of Table 5).

RMF No. 1.2.2

WORLDWIDE CROP ACREAGE AND YIELD MEASUREMENTS AND CROP PRODUCTION FORECASTS

Rationale for Benefits

Accurate forecasts of worldwide crop production provide information for planning and coordination of world trade, allowing the U.S., for example, to identify potential foreign markets for its agricultural exports. Improved data for forecasting can yield benefits not only in increased world trade opportunities, but also in detection of potential regional shortages allowing more efficient mobilization of resources to aid such areas.

In gains from improved information, it is difficult to draw a precise line between domestic (United States) gains and international gains by all countries.

Considerations - problems and opportunities - that even recently were clearly confined to individual nations, or regions within those nations, more and more become inter-related with activities elsewhere. A Soviet fore t on the expected June 1973 - July 1974 wheat crop of the USSR affects commodity prices in Chicago by 5-10% in one week. What this indicates is confidence (maybe misplaced) in pronouncements by obviously interested, and sometimes adverse, parties and the lack of actual *verified information* on world wheat crops.

Thus, decisions, or mere publications on pronouncements of (statistical) estimates anywhere in the world, affect the income and livelihood of people in the United States, and economic decisions made here similarly affect incomes and livelihoods in areas such as the Ukraine, India, and Argentina.

Production, storage, distribution, and further processing of agricultural commodities have to be viewed in the context of worldwide trade, demand, supply, and inventory (stock) needs. From July 1972 to June 1973, 120 million metric tons, or 12% of the total estimated grain production of about 900 million metric tons, were exported/imported between major regions. Exporting countries were the United States (with 69.9 million m.t., or close to 60% of *all* world exports), Canada, Australia, South Africa, and Thailand. Note that three of these are in the Southern Hemisphere. Major importers included: Western Europe with about 20 million m.t.; Japan with 12 million m.t.; USSR with 17.5 million m.t. (net); and

China with 6.2 million m.t. The outstanding development in the past few years has been the sharp increase - across the board - of grain prices. Wheat prices doubled from July 1972 to July 1973, from approximately U.S. $70.00 to about U.S. $140.00 per m.t. The prices of corn similarly doubled in the same period, from U.S. $58.00 to U.S. $125.00.

The total value of the March 1973 world grain trade between major regions, i.e., excluding trade *within* Western Europe, was U.S. $4 billion if valued at July 1972 prices, and U.S. $17 billion if valued at July 1973 prices. This is a 325% difference, due to price fluctuations, of over $8 billion in twelve months. Since 60% of this world grain trade originates in the United States, *any* system promising earlier, better, or more reliable information on U.S. or world acreage, yield, and expected or actual production is a source of potential economic benefits. Paradoxical as it may sound, earlier and better information is of great economic value to both the exporting *and* importing countries; earlier and better information makes arbitrage between *present* and *future* markets possible over a more extended time period, thus equalizing potentially more drastic price movements such as those witnessed in these past months. Earlier and better information also allows more extensive arbitrage operations between different, *more distant* places. "Distance" in an economic sense is often transportation costs and time. For example, wheat crop shortages in some areas of western India might be offset in recognized early and adequately, by crops grown elsehwere in India. Similarly, shortages in Western Europe might be mitigated through timely imports from Argentina, South Africa, or Australia, rather than by violent price movements.

Better and more timely information also allows better decisions in *production*. Some areas in India, North Africa, and Southern United States harvest as early as May of each year, while Australia, Argentina, and South Africa - major grain exporters - harvest during the winter season of the Northern Hemisphere. Production, storage, and distribution decisions in *world* agriculture (with respect to grains, for example), are made on a much more continuous basis than it might first appear. Thus, shortages in the world grain supply, which are actually deficits in some particular regions and crops, could be offset in some cases by appropriate *additional crop production* decisions within the same production-reporting cycle (July-June). Early reliable recognition of the need is required, however.

RMF No. 1.2.2

Federal Government Activities and Responsibilities

The Foreign Agricultural Service, USDA, is responsible for "obtaining statistics and related facts on foreign production" under 7 USC 2201, 2202, passed in 1973. Also required is the compilation of statistics "concerning the production, consumption, and stocks of cotton in foreign countries" under 13 USC 44, passed August 31, 1954. FAS collects acreage, yield, and production figures for major crops in as many countries as possible, employing 61 "agricultural attaches" around the world for data collection, as well as utilizing statistics made available by foreign governments. $8,334,000 was appropriated for the attache program in fiscal year 1975.*

Non-Federal Activities

The Food and Agriculture Organization of the United Nations (FAO) compiles and publishes monthly statistics on world agricultural production. These reports, on crop acreage and prospective yield, consist entirely of data submitted by individual governments; data are requested on land use, irrigation, and insecticide use, as well as on crop production and acreage. While FAO does advise various government statisticians on estimation techniques, it is not responsible for its own data collection. Thus, its budgeted costs of about $1.8 million (for the years 1966 and 1967) represent only a fraction of the total costs for the information it produces.**

The data provided to FAO are in many cases of questionable value. Tables 6 and 7 outline the levels at which data is collected in various countries. While these figures were published in 1955, it is believed that they still accurately represent relative levels of crop enumeration.

These figures appear to reflect more accuracy in enumeration than actually exists, since any country using statistical or guesswork methods that operate in a pre-defined manner on data from even a few single farms, qualifies here

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* The Budget of the United States Government, 1975 G.P.O., 1974.

** Food and Agriculture Organization of the United Nations, Approved Budget 1966/1967, pp. 31-39.

Table 6 Distribution of Countries by Basic Unit of Enumeration* Used in Surveys of Crop Area

Unit of Enumeration	Number of Countries by Region of the World						
	Europe	Asia	North & Central America	South America	Africa	Oceania	Total
Farm or Field	15	7	6	5	10	4	47
Village	3	3	3	1	1	1	12
District	-	6	1	5	5	-	17
Province	-	1	-	-	-	-	1
No Enumeration	-	-	1	-	11	-	12
Total Number of Countries	18	17	11	11	27	5	89

*The "Unit of Enumeration" is the lowest level at which information is collected by agencies responsible for agriculture statistics.

Source: FAO, Methods of Collecting Current Agricultural Statistics, Rome, 1955.

Table 7 Distribution of Countries by Basic Unit of Enumeration* Used in Surveys of Crop Yield and Production

Unit of Enumeration	Number of Countries by Region of the World						
	Europe	Asia	North & Central America	South America	Africa	Oceanic	Total
Farm of Field	5	6	5	4	7	3	30
Village	9	3	5	1	2	1	21
District	3	6	1	6	8	-	24
Province	1	2	-	-	-	-	3
Trade	-	-	-	-	7	1	8
No Enumeration	-	-	-	-	3	-	3
Total Number of Countries	18	17	11	11	27	5	89

*The "Unit of Enumeration" is the lowest level at which information is collected by agencies responsible for agricultural statistics.

Source: FAO, Methods of Collecting Current Agricultural Statistics, Rome, 1955.

as having "farm-level enumeration.* It is clear then that there exists room for a great deal of improvement with commensurate benefits for worldwide farming interests.

Functions of Remote Sensing

The potential of remote sensed data is to provide early, better, and more reliable data on crop acreage, vigor, and yield than are presently available. These data would be not only a vast improvement over those presently available to the U.S. (which are essentially non-existent), but also a source of improved information to other countries about the state of their own agricultural crops.

Economic and Technical Models for Estimating Benefits

Economic benefits estimated herein are of two types:

1) Benefits to the U.S. from improved data on worldwide crop production forecasts, and

2) Benefits to foreign nations resulting from better estimates of their crop production.

U.S. benefits are derived from the U.S. being able to make better import/export decisions based on improved data on worldwide crop forecasts. Greenberg and Bhattacharyya of ECON have developed a rough order of magnitude estimate for these benefits** based on a simple world trade model and the ECON ROM (domestic) Model presented in Appendix E.

ECON has undertaken an extensive economic model** of the import/export market place. Based on the assumption that worldwide crop data from an ERS system would be available to the U.S. *only*, the U.S. could accrue between $121-249 million in annual benefits from improved import/export decisions made with respect to wheat and soybeans. When factored to the import/export value of all crops the U.S. could accrue an additional $145-222 million in annual benefits.

* Food and Agriculture Organization of the United Nations. Methods of Collecting Current Agricultural Statistics. Rome, 1955

** "An Assessment of the Economic Benefits of Continuous On-Demand Earth Observation Data," prepared by ECON and Environmental Research Institute of Michigan for NASA under contract NAS5-20021, 31 August 1974.

RMF No. 1.2.2

Worldwide benefits are derived using the ECON ROM Model presented in Appendix E for each country individually.

In both cases above, economic benefits result from improved inventory depletion decisions based on more certain data. Estimates are made for the wheat crop alone. Total benefits to the agricultural sector are obtained by factoring the wheat-alone benefits to wheat-only benefits for the U.S. domestic public benefits calculated in RMF 1.2.1. This ratio is 3.06.

Current ERTS Activity

The following are current ERTS investigations in the area of worldwide crop acreage and yield measurement.

1) "Agricultural - Livestock Studies" (Argentina)
GSFCID 1528A - F010C - C - 000

2) "Identification and Quantification of Crops, Dynamics of Land Use, and Agriculture Census" (Argentina) GSFCID 1529A - FC01A - C - 000

3) "Soil Survey, Crop Inventory in Conjunction with Aerial Survey" (Netherlands)
GSFCID 1569D - F001D - C - 000

4) "Crop Inventory - Stress Detection - Land Use in Spain"
GSFCID 1623A - F001A - C - 000

5) "Engineering Analysis of ERTS Data for Southeast Asian Agriculture"
GSFCID 1662A - UN01A - C - A000

6) "Coffee Inventory Interpretation Techniques" (Brazil)
GSFCID 1525A - F001A - C - 000

7) "Study of Wheat, Phenology, Vigor, Pests, Disease & Yield" (Netherlands)
GSFC - ID - 1569A - F001A - C - 000

Estimate of ERTS Economic Capabilities

U.S. benefits resulting from a reduction of worldwide forecasting error of wheat to *zero* were calculated by Greenberg and Bhattacharyya to be $396 million per year. Using a ratio of total agricultural sector benefit to wheat-only benefit for domestic U.S. crop forecasting as obtained in RMF 1.2.1 of 3.06, total U.S. benefits are estimated to be $1.211 billion per year.

Worldwide estimates of public benefits of improved ERTS crop acreage and yield estimates are computed using the following assumption and procedures:

1) Yield forecast using agromet models are as accurate when applied to foreign countries as they are when applied to the U.S., given the same accuracy in the boundary conditions. Therefore, errors resulting from growth model projections average 4.2% over the growing season. This is due to uncertainty in the agromet model and uncertainty in the boundary conditions (present crop vigor) used in forecasting yield per unit area.

2) Acreage estimate errors due to ERTS result in an additional forecasting error of 1%. This is well within ERTS capability, as documented in RMF 1.2.1. Therefore, total ERTS-based production errors are taken to be 5.2%.

3) The ECON ROM Model, employing exponential demand function, is used to estimate public benefits. This model is documented in Appendix E.

4) Benefits are estimated only for reduced uncertainty in wheat forecasts, and are averaged over the four years 1970-73 based on a reduction of forecasting errors to 5.2%. Table 8 lists the forecast errors in wheat for the fourteen countries or regions considered.

Table 9 lists gross worldwide public benefits averaged over the last four years, based on an assumed ERTS wheat production forecasting capability having an average error of 5.2%. Average annual worldwide public benefits (excluding U.S.) are $5.417 billion for wheat only.

RMF No. 1.2.2

The following should be noted about the results presented in Table 9.

1) Benefits estimated are rather insensitive to ERS forecast error in the range studied. Reduction in forecast error from 5.2% to 3.0% (42% reduction) increases public benefits in the wheat market from $5.417 billion to $5.624 billion (3.8% increase). Therefore, *on a worldwide scale, moderate estimation capability recovers most of the public benefit.*

2) Zero benefits presented for Canada, Greece, and Italy result because present estimating procedures provide better accuracy than that assumed of the ERS System.

3) The high West German benefits can be attributed to their position in the EEC. Benefits from improved accuracy in the German Government's knowledge of their domestic wheat crop would be in the form of cost savings in their wheat purchase agreements.

4) The extremely high benefit to the USSR is a result of drastic underestimation of their wheat crop in the last four years (22% average). Either the USSR has no capability in crop estimation or they have purposely underestimated their wheat crop in order to take advantage of favorable worldwide wheat prices and shortages.

Using a ratio of total crop benefit to wheat-only benefits for the U.S., derived from the results given in RMF 1.2.1, total benefits to world community due to improved worldwide estimates for all crops may come to $35.752 billion per year.*

Incremental cost of ERS data for worldwide wheat production forecasts is estimated using the following procedure.

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* It must be emphasized that this benefit would accrue to those nations that would make use of freely-distributed ERS data. Benefits to the U.S. having sole access to ERS data have been estimated to be $1.21 billion per year.

RMF No. 1.2.2

Assuming a total crop survey and 100% sampling, an estimate of the total area to be surveyed is obtained. Total U.S. area is approximatley $8x10^6 km^2$. Total U.S. crop area is about 28% of the total or $2.24x10^6 km^2$. World crop area is approximately 10 times that of the U.S. or $22.4x10^6 km^2$ that need to be surveyed. From Appendix D, costs of ERS survey are about $.076 per km^2. Assuming monthly crop surveys worldwide would cause the annual cost of data acquisition to be $20.45 million. Note that this cost is insignificant when compared to worldwide public benefits and essentially insignificant when considering the U.S. benefits in the wheat-only sector.

Annual Benefits

U.S. Import/Export*	New Capability ($121-249 million) for wheat and soybeans only plus ($145-222 million) for other major crops
Non-U.S. Benefits (worldwide availability of ERS data)	up to ($35.8 billion)

* If forecasting error could be reduced to zero, benefits could reach $1.21 billion per year.

RMF No. 1.2.2

Table 8 Preliminary Estimates of World Wheat Production Compared to Final Estimates, 1970-1973

Country	1970 Crop			1971 Crop		
	Production Estimate, Thousands of Metric Tons		Forecast Error, Percent	Production Estimate, Thousands of Metric Tons		Forecast Error, Percent
	Sept.70	Sept.71		Sept.71	Sept.72	
Canada	9208	9023	2.01	13811	14412	-4.35
U.S.	37009	37516	-1.36	44235	44620	-.87
S. America	8170	7980	2.33		8931	
France	12936	12922	.1[illegible]	14566	15360	-5.45
W. Germany	5686	5622	1.1[illegible]	7100	6928	2.43
Greece	2000	1970	1.5[illegible]	1950	1933	.88
Italy	9500	9631	[illegible]	9852	10070	-2.21
Spain	4000	4060		5100	5450	-6.86
U.K.	4148	4174		4500	4824	-7.20
Total W. Europe	43586	43737	-.34	48994	50793	-3.67
E. Europe	23554	22720	3.55	27565	30092	-9.13
U.S.S.R.	72400	80000	-10.49	70000	81900	-17.00
Africa	7629	7377	3.31	7769	7833	-.82
China	23000	24500	-6.52		24000	
India	20000	20093	-.46	23246	23247	-0-
Turkey	7500	8000	-6.66	10000	10700	-7.00
Total Asia	67743	69117	-2.02	71795	73628	-2.55
World	279790	287911	-2.90	304166	323188	-6.25

Source: Issues of "World Agricultural Production and Trade, Statistical Report", FAS, USDA.

RMF No. 1.2.2

Table 8 Preliminary Estimates of World Wheat Production Compared to Final Estimates, 1970-1973 (Continued)

Country	1972 crop: Published Sept. 72	1972 crop: Published Sept. 73	1972 crop: Amount of error	1973 crop: Published Sept. 73	1973 crop: Published Jan. 74	1973 crop: Amount of error
	---1,000 m.t.---		-Percent-	---1,000 m.t.---		-Percent-
Canada	13811	14514	-5.09	17010	17112	-.59
U.S.	42443	42042	.95	47014	46577	.93
S. America	9980	8730	12.53	8520	8950	--5.04
France	16042	18123	-12.97	17206	17844	-3.70
W. Germany	6373	6608	-3.68	4866	6921	-42.23
Greece	1960	1919	2.10	1745	1738	.41
Italy	9455	9423	.34	9140	8958	2.00
Spain	4559	4510	1.08	4025	3932	2.32
U.S.	4430	4761	-7.47	7078	5030	28.94
Total W. Europe	49024	51274	-4.58	498[illegible]	50220	-.77
E. Europe	29986	30490	-2.02	31021	31251	-.74
U.S.S.R.	62300	85800	-37.72	95000	110000	-15.78
Africa	8933	9039	-1.18	8029	8465	-5.43
China	24000	26000	-8.33	27000	27000	-0-
India	25500	26477	-3.83	25500	24923	2.27
Turkey	8500	9500	-11.76	8000	8000	-0-
Total Asia	75135	80309	-6.88	78172	77462	.91
World	300489	330890	-10.11	348620	363269	-4.20

Source: Issues of "World Agricultural Production and Trade, Statistical Report" FAS, USDA.

Table 9 Mean Economic Benefits for Various Countries from Improved Forecasts of Wheat Production,* Average Over Years 1970-197**

Country	Benefits From Reduced Forecast Error Due to ERS, millions of dollars	
	ERS Forecast Error of 5.2%	ERS Forecast Error of 3.0%
Canada	0	7.3
South America	29.3	36.9
E.E.L.	557.0	599.4
East Europe	32.0	43.8
U.S.S.R	4713.8	4833.7
Africa	.3	3.4
China	36.9	59.5
India	***	***
Turkey	27.9	37.3
TOTAL	54.7.4****	5624.0****

* Based on a price for wheat of U.S. $110/metric ton.

** Benefits calculated using ERTS ROM Model.

*** Benefits based on Indian Government statistics are essentially zero, however, Indian Government production statistics as well as their forecasts cannot be accepted as reliable.

**** These are not U.S. benefits, but instead accrue to the world Community.

RMF No. 1.2.3

LIVESTOCK INVENTORIES

Rationale for Benefits

Accurate estimates of livestock populations are vital for efficient planning in all stages of processing. Inventories of cattle are now provided semi-annually; of hogs, quarterly. Supplies continually adjust production based on available estimates. If this adjustment process is based on inaccurate information, wide price fluctuations occur resulting in a net public economic loss.

Federal Government Activities and Responsiblities

The Statistical Reporting Service, USDA, is authorized under the Agricultural Marketing Act of 1946 to make livestock surveys and publish results. Multiple-frame sampling was undertaken in FY 1973 for 29 major livestock producing states, in which 88 percent of U.S. cattle and 83 percent of U.S. hogs and pigs are raised.

Non-Federal agencies are retained by SRS for conducting interviews with a sample of livestock farm operators; these data are then electronically processed to arrive at estimates of cattle, hog and pig populations. An estimated $2,038,000 was required for these operation in FY 1973.

Functions of Remote Sensing

Use of remotely sensed data could allow lower cost generation of inventory estimates. There would be no duplication of capabilities, since the service now contracts for all its livestock survey work. The utility of published inventories would also be increased; time savings in collection of remotely sensed data would reduce the lag between actual surveys and publication of estimates.

Some aerial photograph tests of livestock detectability, made in the Vidya Study, * indicate that cattle and sheep can be detected in aerial panoramic photographs at

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* Remote Sensing, National Academy of Sciences, pp. 205-210.

scales as small as 1:20,000. Reliable sex and age distinctions, however, are not possible at this scale.

Current ERTS Activities

ERTS principal investigator for this study area is:

Oscar Dominguez
Inta-Institute Nacional de Technologia
Agropecuaria
Chile 460
Buenos Aires, Argentina
34-7498 (2656)

Estimate of ERTS Economic Capabilities

It is not expected that ERTS can provide data of sufficient quality on livestock to provide benefits.

Annual Benefits:

None

RMF No. 1.3.1

OPTIMIZE PLANTING SCHEDULES

Rationale for Benefits

Planting at the correct time is essential if maximum yield is to be realized. Advance weather information, combined with inputs on proper conditions for planting specific crops, can result in better information on optimal planting times. Benefits are realized by farm operators, who experience increased crop/yields due to better timing in planting.

Functions of Remote Sensing

Remote sensing can provide improved data on future weather patterns, resulting in better and more timely information on optimum planting times for farm operators, who benefit from increased yield and a reduction in weather-related crop losses.

Estimate of ERTS Economic Capabilities

Benefits were not calculated for this RMF.

Annual Benefits:

None quantified

RMF No. 1.3.2

OPTIMIZE HARVESTING SCHEDULES

Rationale for Benefits

The location and availability of capital-intensive harvesting equipment often determines whether crops can actually be harvested at the optimal time. Benefits can accrue to farm operators from better scheduling of harvesting activities; optimal scheduling can be approached if better information on future weather conditions and ongoing harvest activities are available.

Estimate of ERTS Economic Capabilities

Benefits probably cannot be realized in this area in the short term. Farmers have little or no control over harvest times when they are dependent on large harvesting equipment which travels throughout the growing area; harvest equipment operators, in turn, must complete their work in a specified amount of time and have little flexibility for dealing with local crop conditions.

Benefits were not found for this RMF.

Annual Benefits:

None Quantified:

RMF No. 1.3.3

DETERMINE REGIONAL CYCLICAL PEST AND INSECT INFESTATIONS

Rationale for Benefits

Early detection of pest infestation results in benefits to farmers from decreased loss due to insects; expenditures on pesticides can be decreased if the extent of infestation is accurately charted (see RMF 1.1.5). Determination of regional pest infestation cycles can reduce even further the costs of pest control, since likely areas and times of infestation would be identified in advance. Resources necessary for pest control can be built up ahead of time; more importantly, however, preventative action can be taken where infestations are expected, thus arresting early the spread of destructive pests, and eliminating the higher control costs associated with already established infestations.

Benefits of Remote Sensing

Remote sensing can provide sequential data on pest infestation over time; thus, substantial cost savings may be realized over ground survey methods once ERS capabilities are better understood. See RMF 1.1.5.

Estimate of ERTS Economic Capabilities

Benefits in this area are redundant with those in RMF's 1.1.5 and 1.6.2.

Annual Benefits:

Accounted in RMF 1.1.5 and 1.6.2

RMF No. 1.4.1

ALLOCATION OF AGRICULTURAL LAND TO SPECIFIC CROPS

Rationale for Benefits

Benefits result from the application of more timely and more accurate domestic and worldwide acreage, vigor and yield, and soil condition surveys in making decisions on planting, irrigation, fertilization, pesticide application and harvesting schedules. Benefits, in the form of net gains (profits) to individuals or companies, are derived from better information. Such gains are often at the expense of "others" -- the sellers, the buyers, and other intermediaries. Additional benefits accrue to the public sector, for example, from reductions in needed government support programs. Benefits from use of the improved data can result from:

1) Cost savings through reduced fluctuation in acres used for producing certain crops, thus, lower unit product costs.

2) Increased yields and reduction of losses through more timely harvesting.

3) Increased profits from better planting decisions based on more accurate and timely domestic and worldwide production forecasts.

Federal Government Activities and Responsibilities

Most government activities in this resource area deal with the actual gathering of statistics on crop acreage and yield detailed in RMF. 1.2.1.

Functions of Remote Sensing

Remote sensing would be the source of more timely and accurate data on acreage and expected yield. Timeliness of the information would be improved since it is presently obtained by questionnaire (see RMF 1.2.1). Accuracy, especially on worldwide estimates, would be greatly improved, because data gathering would be centralized and uniform estimates would be available from all areas of the world.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

The effects of improved information on production within the U.S., or even very gross information on production elsewhere and its influence on U.S. production decisions have nowhere been credibly analyzed. Except for broad qualitative statements, an improvement cannot be made until agricultural production is empirically explained including the effect of improved information on production. A very rough estimate of benefits for U.S. domestic information only (excluding worldwide information and its effect on U.S. production decisions) is about 25% of the distribution benefits of improved information presented in RMF 1.2.1. The derivation of this percentage is rather crude, based on the elasticity of U.S. agricultural production functions and a "visual" comparison of public economic gains there from those compared to distribution/demand related considerations.

An educated guess at domestic production effects of improved information is between \$9 million (low) and \$77 million (high) with a "likely" estimate of about \$36 million.

Quantification of the public gain from *greater certainty* is not attempted as too many institutional and subjective factors enter such estimates. The *effects* of *providing* certainty (government agricultural support programs) have been variously estimated as an increase in agricultural output of 30 to 40% when compared to production with such supports. (This is \$1-\$15 billion for 1973 values.) Of course, elsewhere and all too easily, one makes the fallacious assumption that these government support programs come "free of charge" and that therefore, there can be no value to improved information in these matters; quite the contrary is the case.

Current ERTS Activities

Only one current ERTS investigation is studying the use of ERTS data for better allocation of agricultural land: "To Find Areas of Probable New Agricultural Development" GSFC ID 1631E-FC01H-C-0000.

Estimates of ERTS Economic Capabilities

Current estimates of the benefits of improved information include:

1) Heiss* indicates that the infinite horizon range of annual social benefits in domestic crop production due only to improved crop acreage and yield estimates is between

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*Heiss, K.P. "An Evaluation of the Value of Improved Information on Agriculture," ECON, Inc. July 1974.

$9.4 million and $76.8 million. Potential private benefits from improved domestic ERTS information can range from zero to 10 times larger than the social gains. See Table 10 below.

Annual Benefits:

New Capability ($15.4 - 118.8 million)

Table 10 Annual Social Benefit Estimates Due to Improved Allocation of Agricultural Land Resulting From ERTS-type Data

	Low Production	Expected Production	High Production
Barley	Small	Small	Small
Corn	1.5	6.2	13.1
Cotton	1.2	5.1	9.4
Potatoes	--	--	--
Rice	--	--	--
Sorghum	--	--	--
Soybeans	8.6	20.3	61.3
Sugarbeets	--	--	--
Wheat	4.1	16.2	35.0
Totals	15.4	47.8	118.8

Source: Heiss, K.P., "An Evaluation of the Value of Improved Information on Agriculture," ECON, Inc. July 1974.

RMF No. 1.4.2

ALLOCATION OF STOCK BREEDING AREAS

Rationale for Benefits

Improved inventories of grazing land could lead to better locational decisions with respect to stock breeding areas. Managers of livestock make decisions on breeding areas using statistics on the kind of livestock, use, breed, sex, age and vigor as well as factors affecting the animal carrying capacity (stock decisions) of an area, including the amount, palatability, accessibility and nutritive value of each species of forage and the location of stock-poisoning plants, noxious weeds, springs, salt grounds, watering places, highly erodible sites and areas of reseeding.

Functions of Remote Sensing

Some aerial photography tests of livestock detectability made in the Vidya Study*, indicated that both cattle and sheep could be detected in aerial panoramic photographs at scales as small as 1:20,000. Reliable sex and age distinctions were not possible. Remote sensing could also be used to provide better information on locations on noxious weeds, springs, salt grounds, watering places and highly erodible sites.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

The resolution used in the Vidya study is slightly beyond present ERTS-type capabilities. For this reason it is not expected that ERTS can yield large benefits in this area.

Estimate of ERTS Economic Capabilities

Even though some evidence has shown that remote sensing can detect livestock, it is felt that the data is not of sufficient quality to result in significant improvements in the allocation of stock breeding areas. Benefits are considered to be zero.

Annual Benefits:
None

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* Remote Sensing, National Academy of Sciences, pp. 205-210.

RMF No. 1.5.1

SOIL CONSERVATION

Rationale for Benefits

An effective program of soil conservation yields benefits in reduced losses from wind and water erosion, and in the prevention of soil deterioration, with subsequent loss of productive capacity, due to misuse of agricultural lands. Reductions in erosion also lead to improved regional water quality, since topsoil runoff, with consequent silt and chemical pollution, is reduced.

Although there is no satisfactory method for economic evaluation of physical soil deterioration of cropland on a national scale, various estimates have been made.* The annual losses from erosion alone, in terms of the cost of replacing with commercial fertilizers the major nutrient elements removed through soil erosion, are estimated at over 4 billion dollars. Estimates made of annual losses are

$1.14 B Erosion of cropland by wind and/or water

.504 B Deterioration of soil structure

Soil erosion alone has forced the abandonment for cultivation of an estimated 35 million acres of land that was originally suitable for crop production.

Conservationists and resource planners can use information on erosion patterns to take appropriate preventative actions; measures can also be taken to reduce damages from flooding if warnings come early enough. Farmers can use information on structure and overall conditions of soils to choose planning patterns and crop rotation schedules which will maximize production while preserving soil quality.

Federal Government Activities and Responsibilities

The Soil Conservation Service (SCS), USDA, carries on extensive conservation work, in cooperation with over 3000 local "conservation districts", which serve over 2,300,000 users, mostly farmers and ranchers. $162 M has been appropriated for the overall conservation effort in FY 1975, a

* USDA "Losses in Agriculture", Agriculture Handbook #265, 1965.

$15 M increase over 1974; this figure does not include $25M for SCS soil surveys, which provide some of the most important inputs for planning of conservation measures (see RMF No. 1.1.3).

The Function of Remote Sensing

Remote sensing can provide more extensive and more timely data on soil conditions and on patterns of erosion. An accurate remote sensed overview of an erosion area can allow more efficient and effective control measures, thus cutting losses. Losses can also be reduced if erosion is detected at an earlier stage; swifter preventative actions help prevent further damage.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Benefits of remote sensed data result from a reduction in losses due to erosion, made possible by more timely and more accurate identification and delineation of erosion zones. Benefits are calculated as the percentage reduction in total estimated losses from erosion and soil deterioration made possible with the use of remote sensed data.

Current ERTS Activities

ERTS principal investigators for this resource are.

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HQ United States Army, IAGS
For. Eros Guatemala
APO New York, N.Y. 09827
63821

Roger B. Morrison
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Athens, Greece
651-212

RMF No. 1.5.1

Morrison* has made an extensive study of continuing erosion in Southern Arizona, using ERTS imagery covering 17,000 square miles. He found that ERTS imagery can be useful in:

1) Identifying areas affected by erosion
2) Measuring severity of damage
3) With repeated passes, monitoring the rate of erosion

Morrison also notes that much of the land lost since 1890, the beginning of this episode of erosion, was once excellent pastureland or irrigated farmland; detection and prevention of such losses in the future, as well as present losses, can be realized with ERS identification and monitoring of erosion zones.

Estimate of ERTS Economic Capabilities

SCS does not at present have the resources to monitor such events as the bringing of new lands into production, although it gives top priority to requests for assistance from farm operators contemplating such a move, and offers advice and guidance. Along with weather fluctuations, new cropping is a prime instigator of accelerated erosion. In 1973, for example, Texas reported 907,147 acres of cropland damaged, due to wind erosion alone, almost 700 percent more than in 1972; South Dakota reported a 300 percent increase in damaged land.

The major contribution of an ERS system in reducing erosion and soil deterioration losses may be its essentially 100% coverage, allowing identification and delineation of major erosion areas within a matter of months. Other areas, such as oven-dry fields, which might be susceptible to damage at any time, can also be identified, and losses, hopefully, averted.

It is difficult to quantify losses of this type, and just as difficult to estimate what impact an ERS system may have. As much as 10% of annual erosion losses might be eliminated with ERTS identification combined with quick ameliorative action. Even a 1% reduction in losses from erosion and soil structure deterioration would yield an

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* R.B. Morrison and M.E. Cooley, Application of ERTS-1 Multi-spectral Imagery to Monitoring the Present Episode of Accelerated Erosion in Southern Arizona. NASA SP-327, paper G7.

C-2

RMF No. 1.5.1

annual benefit of $16.4 million. The expected value of ERTS benefits is taken to be 5% of annual losses, or $82.2 million, with a lower bound of $16.4 million and an upper bound of $164 million.

Annual Benefits:

New capability ($82.2 million)

RMF No. 1.6.1

AGRICULTURAL CROP DISEASE PREVENTION

Rationale for Benefits

Benefits of more accurate and more timely information on the extent of crop disease accrue from two sources: (1) reduced cost resulting from more efficient use of combative measures and (2) increased yields due to the arrest of the disease.

Common methods of controlling plant disease includ (1) use of disease-resistant varieties; (2) cultural practices such as deep plowing to bury infested crop residues, rotating crops to avoid a buildup of disease inoculum, burning infested plant debris, shifting production areas to avoid diseases, removal of alternate hosts, controlled irrigation, use of fertilization and other management practices, and use of disease-free seed; (3) biological control, principally for soil diseases such as root rots and wilts; and (4) use of chemicals for treating seed, disinfesting soil, and as sprays and dusts applied to the plants to control diseases and insect sectors of plant diseases.

The Southern Corn Leaf Blight epidemic in 1970 alone caused losses that exceeded $1 billion. Less conspicuous and unspectacular diseases that often go undetected prevent growers from maximizing production. A joint state-federal task force in 1965* reported that diseases annually reduce national average grain yields of corn by 12 percent and grain sorghum by 9 percent. Thus, for every 1 percent increase in yield through disease prevention and control, an additional 55 million bushels of corn would be harvested. In similar reports, estimates of direct costs attributable to diseases in cotton are represented collectively as approximately 28 percent of the costs incurred in the production of cotton. Losses in wheat and other small grains were estimated at 10 to 20 percent annually. In fact, disease was reported responsible for a 30 percent reduction in wheat yields in Indiana in 1973.

Market value of losses due to disease in the 13 leasing crops listed in Table 11 came to $3.8 billion in 1972. Public economic losses amounted to $2.2 billion in 1972.

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* Losses in Agriculture, Department of Agriculture Handbook #291, 1965.

RMF No. 1.6.1

The total cost of controlling plant diseases is estimated at $116 million annually for the period 1951-60 (Table 12). Estimates of control costs are difficult and are made only for chemical control ($100 million), and for the costs involved in producing disease-free planting materials ($8 million). Approximately $75 million is paid for fungicides by farmers and commercial applicators. It is estimated that 1,000,000 acres of fruit and nut trees are treated on an average of four times a year, 1,500,000 acres of potatoes are treated four times. At an average cost of $2 per acre the total cost of application of fungicides is approximately $25 million.

Most recently (1974) major United States wheat exports to China were refused acceptance by China due to extensive - albeit marginal - bacterial infestation.

The expense of controlling diseases in a particular crop varies considerably. For example, on potatoes grown in the arid West, foliage diseases are of little importance. In Maine, the 8 to 14 applications to control late blight cost $30 to $50 per acre. Growers of apples in the Pacific Northwest usually have to spray three to four times during the season; in the East, they have to spray 8 to 20 times. Each application costs approximately $8 per acre.

Federal Government Activities and Responsibilities

Plant Quarantine and Regulatory Measures

The enforcement of quarantines affecting importation and interstate movement of plants, plant products, plant pests, soil, and miscellaneous nonagricultural importations found contaminated with pests cost approximately $4 million annually during the period 1951-60. This estimate includes (1) Federal appropriations for foreign plant quarantines; (2) contributions by States and offshore possessions, particularly California, Hawaii, and Puerto Rico, to the plant quarantine program; and (3) costs to importers in connection with the inspection, treatment, handling, and other incidentals to meet plant quarantine import requirements. The expense of fumigating or otherwise treating large quantities of imported cotton and cotton products, broomcorn, fruits, vegetables, used bagging, carriers, and contaminated nonagricultural cargoes is included in this last group. The

Table 1 1 Social Costs and Benefits of Disease Reduction in Field Crops - With and Without ERS

Crop	% Production Loss Due to Disease[1]	Domestic 1972 Crop Value $ billions (1973)	ROM Price-Demand Elasticity	Net Public Cost of Disease Infestation[2] $ millions (1973)	ROM Benefit of 1% Reduction in Production Loss[3] $ millions (1973)	ROM Benefit of 10% Reduction in Production Loss $ millions (1973)
Corn	12	7.017	0.1	490.35	8.370	79.35
Soybeans	14	4.451	0.3	497.95	6.217	60.88
Hay	24	3.662	0.1	332.98	8.684	78.14
Sugarbeets	16	0.456	0.08	31.54	.722	6.61
Wheat	14	2.575	0.15	234.36	3.59	34.42
Cotton	12	1.743	0.1	121.80	2.08	19.71
Tobacco	11	1.442	0.5	142.38	1.58	15.69
Citrus	15	0.857	0.3	101.16	1.28	12.54
Sorghum	9	1.041	0.1	61.78	.93	8.96
Potatoes	19	0.751	0.1	63.87	1.41	12.99
Rice	7	0.562	0.1	28.29	0.39	3.80
Peanuts	28	0.477	0.2	71.87	1.33	12.46
Oats	21	0.471	0.1	41.33	0.98	8.92
Total	--	$25.505	--	2,219.67	37.57	354.48

[1] Estimated from 1951-60 data in Losses in Agriculture, USDA

[2] Estimated using exponential demand function.

[3] Estimated using equation 1.6.2-4.

RMF No. 1.6.1

Table 12 Controlling Diseases in the Production of Crops: Estimated Average Annual Cost, 1951-60

Type of Control	Average Annual Cost, $ thousands (1960)
Chemical control:	
Fungicides	75,000
Application of fungicides	25,000
Total	100,000
Seed disinfectants	7,000
Production of disease-free planting stock	
Ornamental plants	2,400
Sweetpotatoes	150
Potatoes	6,200
Fruit crops	50
Total	8,800
Grand Total	115,800

Source: Losses in Agriculture, USDA Handbook #291, 1965.

fumigation of ships and cargoes found to carry the khapra beetle and injurious snails was especially heavy during the latter part of the 10-year period covered by this report.

At present there exists no national plant disease and detection program; however, such a program is being proposed by the American Phytopathological Society. The program proposes to establish a nation-wide network of crop disease detection, reporting and information exchange stations. Objectives of the network are:

a. To help reduce major disease outbreaks by:

1. providing a means for detecting and monitoring plant disease development in all major food, feed and fiber crops.

2. providing basic data for the operation of an effective integrated pest management program.

3. providing research lead time to respond to the presence of a new pathogen before it becomes necessary to control the disease it incites.

4. providing for more efficient dissemination of timely information for crop production and plant disease forecasting.

5. providing a means for storage and rapid retrieval of current and stored information on disease development in crops and thus serving to alert pathologists and others in neighboring states or regions on the disease situations.

6. providing information for the judicious, economical and effective use of chemicals for plant disease control.

b. To provide a basis for issuing phytosanitary certificates required by foreign countries for United States agricultural exports, an obligation of the United States to the International Plant Protection Convention of 1951.

c. To provide an inventory and permanent record of plant disease development in the United States. The information is to serve as a basis for the initiation of action programs by regulatory, extension and research agencies in the United States.

A proposed annual budget of about $2.5 million is reported to be sufficient to establish the information distribution aspects of the network; however, the data gathering aspect, especially for plant disease indicator plots requires data best obtained by remote sensing. It is expected that this information network could lead to a 15% across the board reduction in losses due to insect infestation.*

Functions of Remote Sensing

Remote sensing can be used to monitor the vitality of the crop, determine the extent of crop infestation, and assess the effectiveness of the insect control measures. More timely, area-wide and continuous data from remote sources could reduce the cost of control methods as well as minimize the losses due to the infestation.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Assuming a rational economy, the area under the price-quantity demand curve represents the public benefits derived from a given production level. Reduction in production leads to reduction in area; therefore public losses. As developed in RMF 1.6.2, reduction in losses results in a recovery of public gains. The benefits of that increased production can be represented by the return in public benefits due to the resulting increase in production. Equations 1.6.2-3 and 4 represent rough order of magnitude estimates of the public benefit.

It is not expected that the improved data on insect infestation will lead to any significant change in the amount of insecticides used. Instead a better allocation in terms of timeliness and distribution of those insecticides will be the mechanism by which the improved data will result in reduced losses.

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* Losses in Agriculture, USDA

RMF No. 1.6.1

Current ERTS Activities

The following are currently funded ERTS activities in this area:

1. "Detection of Plant Diseases & Nutrient Deficiencies; Soil Types; & Moisture" GSFC ID GSFC ID 1139A-UN01D-C-A000.

2. "Study of Wheat, Phenology, Vigor, Pests, Diseases and Yield" GSFC ID 1569A-Foo1A-C-000

Estimate of ERTS Economic Capabilities

Table 11 presents a rough order of magnitude estimates of public benefits of ERS technology in the area of reducing disease losses in thirteen (13) leading field crops. It is expected that continuous monitoring of crops from remote sources could result in at least a 1% reduction in production losses due to disease and possibly as great as a 10% reduction in production losses could result. Based on a 1% recovery of production losses, annual public benefits are $37.57 million and $354.48 million based on a 10% recovery of production losses.

Costs of obtaining sufficient ERS data for vigor to monitor stress due to insects, disease, irrigation and/or weeds is obtained by assuming

1. 100% coverage of all major agricultural areas every week of the growing season March - September

2. Cost of ERS data as presented in Appendix D

Present U. S. crop acreage is 2.24 x 10^6 km^2. Based on an average cost of ERS data of \$.194/mi^2 implies that each weekly coverage costs $165,000 and seasonal coverage is 28 x 165,000 = $4,6 million. This should provide sufficient data for detailed stress monitoring. These costs are subtracted from gross public benefits after their aggregation into the Section 1.6.

Annual ROM Benefits:

Increased capability ($38-354 million)

RMF No. 1.6.2

AGRICULTURAL CROP INSECT INFESTATION PREVENTION

Rationale for Benefits

Of the approximately 10,000 species of insects in the U.S. that are injurious enough to be called "public enemies" about four-fifths are injurious to crops. They reduce the yield, lower the quality, contaminate the market product, and increase the cost of producing, processing and marketing the crop. Insect losses to many crops vary drastically from year to year. Average annual loss caused by insect pests to various groups of crops (years 1951-1960) are given in Table 13. The loss in market value of the 10 most valued domestic crops comes to $1,838 billion per year (1972). A detailed breakdown of losses to specific field crops is given in Table 13. Losses of potential production due to insect infestation average about 10 percent of yield.

More accurate and more timely data on insect information can result in two types of benefits: (1) reduction in crop losses due to earlier and more effective combative action and (2) cost savings from more efficient use of insecticides.

Average annual cost of controlling insect infestations in the 1951-1960 decade (exclusive of the enforcement of quarantine and regulatory measures and the operation of large scale cooperative pest control programs, see RMF 1.6.1.) was about $425 million (1960). (These controlling measures used were developed through research whose cost is not included in the above figure.)

The largest component of cost [$240 million (1960)] comes from the use of insecticides; however, $1 million per year was spent utilizing natural enemies and developing resistant strains as a means of combating harmful insects.

Federal Government Activities and Responsibilities

See RMF 1.1.5

Functions of Remote Sensing

Remote sensing may be used to monitor the vitality of the crop, determine the extent of crop infestation, and assess the effectiveness of the insect control measures. More timely, area-wide and continuous data from remote sources could reduce the cost of control methods as well as reduce the losses due to the infestation.

Table 13 Public Costs and Benefits of Insect Infestation of Field Crops -- With and Without ERTS

Crop	Percent Production Loss Due to Insects[1]	Domestic 1972 Crop Value $ billions (1973)	ROM Price-Demand Elasticity (1973)	Net ROM Cost of Insect Infestation[2] $ billions (1973)	Public ROM Benefit of 1% Reduction in Production Loss[3] $ millions (1973)	Public ROM Benefit of 10% Reduction in Production Loss $ millions (1973)
Corn	12	7.017	0.1	0.4904	8.370	79.35
Scybeans	3	4.451	0.3	0.1271	1.335	13.29
Hay	--	3.662	0.1	--	--	--
Sugarbeets	12	0.456	0.08	0.0283	0.543	5.08
Wheat	6	2.575	0.15	0.1273	1.542	15.15
Cotton	19	1.743	0.1	0.1482	3.280	30.16
Tobacco	11	1.442	0.5	0.1424	1.584	15.69
Citrus	--	0.857	0.3	--	--	--
Sorghum	9	1.041	0.1	0.0618	0.933	8.96
Potatoes	--	0.751	0.1	--	--	--
Rice	4	0.562	0.1	0.0185	0.224	2.20
Peanuts	6	0.477	0.2	0.0247	0.286	2.82
Oats	4	0.471	0.1	0.0155	0.188	1.85
Total				1.842	18.285	174.55

[1] Estimated from 1951-60 data in Loss in Agriculture, USDA

[2] Estimated using exponential demand function.

[3] Estimated using equation 1.6.2-4.

RMF No. 1.6.2

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

From the economic principle that annual net social benefits in a rational economy are measured as the area under the (price vs. quantity) demand curve between zero production and the annual production, reductions in production, for any reason, lead to losses in public benefits, i.e., public costs. Public costs can be reduced by recovering some of the lost production. In Figure 7, below, if Q^* is the expected production, Q_0 the production without ERTS data and Q_1 the production with ERTS data then

(a) the area Q_0BAQ^* is the loss due to (say) insect infestation, and

(b) the area Q_0BCQ_1 is the reccvered loss, i.e., gross benefit, attributable to ERS data.

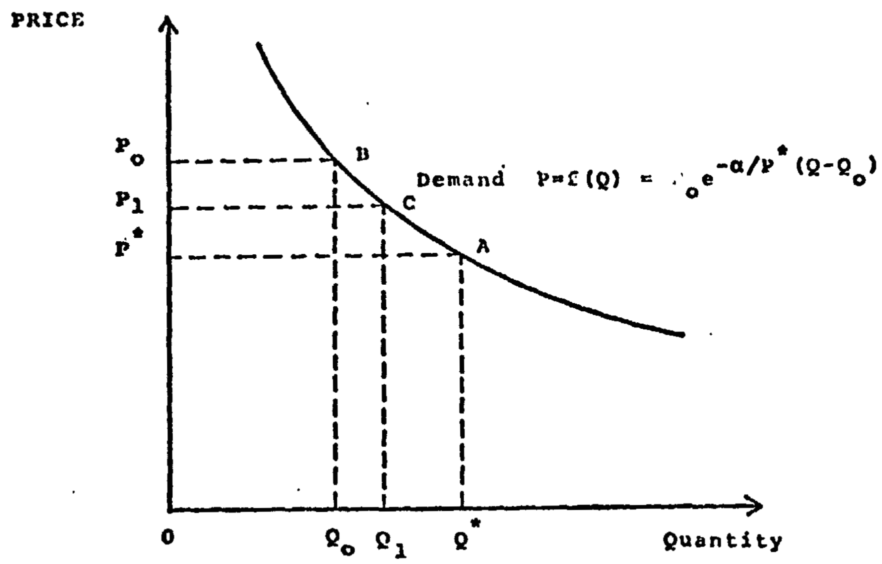
Costs of insect infestation, PC, are then

$$PC = \int_{Q_0}^{Q^*} f(Q)\,dQ \qquad 1.6.1.-1$$

and gross benefits of ERTS, PB, of improved insect control due to improved data are

$$PB = \int_{Q_0}^{Q_1} f(Q)\,dQ \qquad 1.6.2.-2$$

Since in general $Q_1 - Q_0$ (.01 to .1) will be small, a linear representation of the demand curve is valid; however, for estimating ROM costs a linear assumption of the demand curve may lead to negative prices at Q^*. Thus, a non-linear demand curve is needed. In the ECON ROM Model an exponential form for the demand curve as used in the RMF 1.2.2 is used



$Q^* = (1 + \varepsilon_1)\, Q_o$

$Q_1 = (1 + \varepsilon_1 \beta) Q_o$

ε_1 = % production loss/100

β = % production $\frac{\text{loss recovered}}{100}$ due to ERS data

Figure 7 Demand Curve for Agricultural Crops

to modify the Hayami-Peterson Model. If α is the price-demand elasticity at Q_o then

$$PC = P_0 Q_0 \alpha (1 - e^{-\varepsilon_I/\alpha}) \qquad 1.6.2.-3$$

and

$$PB = P_0 Q_0 \beta \varepsilon_I (1 - \tfrac{1}{2}\beta^2 \varepsilon_I^2/\alpha) \qquad 1.6.2.-4$$

RMF No. 1.6.2

Net benefits of more timely and more accurate data on insect infestation is the sum of the benefit of recovered production due to more timely and more accurate combative procedures plus (minus) the net savings (increase) in expenditures in combative techniques (insecticides) minus the cost of the ERS data. It is expected ERS data would result in more timely and better distribution of combative techniques, thus rendering this term to zero value. For ERS data to be useful, complete monitoring of all agricultural land during the entire growing season would be necessary. This is the same requirement as is needed for each of the 1.6 RMFs. Therefore, the computation of net public benefits will be calculated only for the entire 1.6 group of RMFs, see RMF 1.6.1.

Current ERTS Activities

The following are presently funded ERTS activities:

1) "Evaluation of Remote Sensing as a Management Tool in Controlling Pink Boll Worm in Cotton" GSFC ID 1084A-UN01A-C-A000.

2) "Gypsy Moth Investigation" GFC ID 1679A-AG01G-C-000.

3) "Study of Wheat, Phenology, Vigor, Pests, Diseases and Yield" GSFC ID 1304A-ST071-D-A000.

ERTS related literature:

1) "ERTS Surveys a 500km^2 Locust Breeding Site in Saudi Arabia" by D.E. Pedgley. Presented at Third ERTS Symposium, March 1973. The experiment demonstrated the feasibility of detecting potential locust breeding sites by satellites.

Estimate of ERTS Economic Capabilities

At present, no satisfactory model exists for predicting the impact of continuous crop information that could be used to accurately identify areas of insect infestation. At present, monitoring of crop land for abnormal growth due to insect or disease infestation is done (if at all) by random 1 percent survey. Exchange of information on insect infestations between even neighboring areas is slow and almost ineffective. The main reason for the lack of data has been the absence of an effective way of area-wide continuous monitoring of agricultural land. It can be assumed that data from a family of ERS-type satellites providing essentially continuous coverage could be used to reduce losses due to insect infestation by at least one percent and as much as ten percent. Total domestic ROM benefits of these increased yields are presented in Table 14. Total gross ROM benefits from an ERS system in the reduction of agricultural crop disease ranges between $18.29 million to $174.55 million per year.

Annual ROM Benefits:

Increased capability ($18 - 175 million)

RMF No. 1.6.3

AGRICULTURAL CROP WEED INFESTATION PREVENTION

Rationale for Benefits

Benefits will result from the use of more timely and more accurate information on the level of weed infestation in implementing the best weed controlling techniques, thus increasing crop yield. Benefits may also result from cost savings from using more efficient methods of weed infestation prevention.

Average annual market value losses due to weed infestation in agriculture to the eleven leading crops was $2.382 billion in 1972. Average annual costs of controlling weeds was estimated to be $3.319 billion per year. Breakdowns of controlling costs for 1960 are presented in Tables 14 and 15.

Losses caused by weeds and the cost of their control are some of the highest in the production of food, feed and fiber. Weeds increase the cost of labor and equipment; reduce the quantity and quality of crops, and also harbor insects and diseases.

Functions of Remote Sensing

Remote sensing can provide more accurate, continuous and area-wide data on the level, type, and effects of weed infestation. Such information can be used for the implementation of more timely and more efficient means of combating the infestation; savings accrue from improved yield and from cost savings in controlling measures.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Public ROM benefits resulting from reduced losses due to weed infestation have been estimated using the methodology presented in RMF 1.6.2. Benefits result from the reduction of public losses due to reduced production. Since such a large amount is presently being spent to control weeds today ($3.3 billion/year) for area-wide repeated controlling of weed infestation expected reduction in losses from improved data are not expected to be large. It is expected that losses could be reduced by at least 0.1% and may be as much as 1% but 10% reductions are not likely. Equations 1.6.2-3 and -4 are

Table 14 Weeds: Estimated Average Annual Cost of Control in Various Crop and Noncrop Areas by Cultural and Chemical Methods, 1951-60*

Crop and noncrop area	Average Annual Costs, $ thousands (1960)		
	Cultural Methods	Chemical Methods[1]	Total
Field and seed crops	1,745,977	92,023	1,876,000
Horticultural crops	307,000	3,050	310,050
Hay crops, pastures, and rangelands	348,308	16,692	365,000
Aquatic and noncrop areas	--	--	55,637
Total	2,401,285	111,765	2,606,687

1 Data are for 1959 only.

2 Includes $21,000,000 for costs of cultural and chemical control of weeds in flax and $17,000,000 for these costs in sugarcane.

* From <u>Losses in Agriculture</u>, USDA Agriculture Handbook #291, 1964

RMF No. 1.6.3

Table 15 Field Crops: Estimated Average Annual Cost of Controlling Weeds by Cultural and Chemical Methods, 1951-60*

Crop	Average Annual Cost, $ thousands (1960)		
	Cultural Methods	Chemical Methods[1]	Total
Corn	496,020	37,980	534,000
Cotton	437,872	4,628	442,000
Beans, dry	33,000	--	33,000
Sorghum, grain	53,489	6,511	60,000
Rice	23,112	888	24,000
Small grains:			
Barley	76,905	3,095	80,000
Oats	130,000	4,000	134,000
Wheat	293,000	30,000	323,000
Alfalfa (seeds)	16,225	775	17,000
Other grass and legume seed crops	39,907	1,093	41,000
Soybeans	99,687	2,313	102,000
Flax	--	--	21,000
Peanuts	19,881	116	20,000
Sugarbeets	27,376	624	28,000
Sugarcane	--	--	17,000
Total	1,745,977	92,023	1,876,000

[1] Calculated from average costs incurred by farmers and other land owners in States reporting, Alaska, California, Delaware, Hawaii, New Jersey, New York, Ohio, Oklahoma, and Washington not included. Costs based on data for one year, 1959.

* From Losses in Agriculture, USDA Agricultural Handbook #291, 1964.

used to estimate annual benefits of reduced production losses due to weed infestation.

Current ERTS Activities

Only one experiment has been conducted in this area and it was found that remote sensing from satellite of herbaccous weeds was possible.

Estimates of ERTS Economic Capabilities

Table 16 summarized probable ROM benefits of ERS based data for reducing crop production losses due to weed infestation in eleven leading field crops. It is expected that continuous monitoring of crops from remote sensing could result in at least a 0.1% reduction in production losses and possibly as much as a 1% reduction. Ten per-cent reduction seems to be beyound the capability of present weed combative techniques. ROM benefits resulting from a 0.1% reduction in losses are $2.38 million/year and $23.72 million year for 1% reduction in losses.

Annual ROM Benefits:

Increased capability: ($2.4 - 23.7 million)

Table 16 Public Costs and Benefits of Weed Infestation of Field Crops -- With and Without ERTS

Crop	Percent Production Loss Due to Weeds[1]	Domestic 1972 Crop Value $ Billion (1973)	ROM Price-Demand Elasticity	Net Cost of Weed Infestation[2] $ Million (1973)	ROM Benefit of 1% Reduction in Production Loss[3] $ Million (1973)	ROM Benefit of 10% Reduction in Production Loss $ Million (1973)
Corn	10	7.007	0.1	443.56	.701	6.982
Soybeans	17	4.451	0.3	577.63	.756	7.545
Hay	--	3.662	0.1	--	--	--
Sugarbeets	8	0.456	0.08	23.06	.036	.363
Wheat	12	2.575	0.15	212.70	.309	3.078
Cotton	8	1.743	0.1	95.98	.139	1.389
Tobacco	--	1.442	0.5	--	--	--
Citrus	4	0.857	0.3	32.09	.034	.343
Sorghum	13	1.041	0.1	75.73	.135	1.344
Potatoes	3	0.751	0.1	19.46	.022	.225
Rice	17	0.562	0.1	45.93	.095	.947
Peanuts	15	0.477	0.2	50.33	.072	.713
Oats	17	0.471	0.1	38.49	.080	.794
Totals		$25.505		$1,614.97	2.379	23.723

1 Estimated from 1951-60 data in Losses in Agriculture, USDA

2 Estimated using exponential demand function

3 Estimated using equation 1.6.2-4

RMF No. 1.6.4

AGRICULTURAL CROP STRESS REDUCTION

Rationale for Benefits

Reduction of crop stress, thus increasing yield and obtaining cost savings by making more efficient use of fertilizer and irrigation resources, may be expected by more detailed and continuous monitoring of plant vigor.

Function of Remote Sensing

Remote sensing can provide timely, continuous and area-wide data on plant vigor. The timeliness of the information can therefore be used to make better allocations of fertilizer and irrigation resources.

Economic and Technical Models for Estimating Benefits

Benefits of improved data on crop stress accrue from better management of irrigation water to reduce losses in crop yield. Benefits of improved irrigation practices are accounted in RMF 3.4.4. Additional benefits if included here would constitute "double counting."

Current ERTS Activities

JSC present plans are in the area of SR&T efforts that would develop improved methods for detecting, monitoring and possibly identifying the predominant agricultural crop stresses. Exploratory activities could begin with assessing the value and use of thermal IR data in detecting stress. A thematic mapper ground cell of 1/4 acre should be sufficient to begin evaluating the stress/yield objective capability.

Estimate of ERTS Economic Capabilities

Definite benefits may accrue from reduced losses due to crop stress; however these accrue from improved allocation of irrigation resources and have therefore been accounted in RMF 3.4.4.

Annual Benefits:
Increased capabilities accounted in RMF 3.4.4

RMF No. 1.6.5

ASSESSMENT OF DAMAGE TO AGRICULTURAL CROPS DUE TO DISEASE, INSECT AND WEED INFESTATION, STRESS, FROST AND OTHER WEATHER PHENOMENA

Rationale for Benefits

Benefits would result from cost savings in the timely identification of damage to agricultural crops. Other benefits result from more accurate assessment of damage to agricultural crops so that farmers receive just compensation for their actual losses and the Federal Government and insurance companies avoid overpayments.

Some of the cost savings benefits to the Federal Government overlap those of RMF 1.1.6 and are not considered here.

Federal Government Activities and Responsibilities

FEDERAL CROP INSURANCE CORPORATION

Purpose Statement

The Federal Crop Insurance Corporation is a wholly-owned Government Corporation created February 16, 1938 (7 U.S.C. 1501) to carry out the Federal Crop Insurance Act. The purpose of this Act is to promote the national welfare by improving the economic stability of agriculture through a sound system of crop insurance and providing the means for research and experience helpful in devising and establishing such insurance.

Crop insurance offered to agricultural producers by the Corporation provides protection from losses caused by unavoidable natural hazards, such as insect and wildlife damage, plant diseases, fire, drought, flood, wind, and other weather conditions. It does not indemnify producers for losses resulting from negligence or failure to observe good farming practices.

The 1974 crop insurance programs operate in 1,442 counties, furnishing insurance coverage of approximately $955 million on apples, barley, beans, citrus combined crop, corn, cotton, flax, grain sorghum, grapes, oats, peaches, peanuts, peas, raisins, rice, soybeans, sugar beets, sugarcane, tobacco, tomatoes, and wheat. It is estimated that 317,000 crops will be insured for the 1974 crop year, as compared with 318,000 for the 1973 crop year.

Estimated FY loss adjustment cost (non-administrative and operating expenses) paid by the FCIC is $2.6 million. These funds are primarily spent for the assessment of crop losses.

Functions of Remote Sensing

Remote sensing would provide accurate and timely estimates of crop losses due to disease, weeds, insects and/or floods. Time series crop vigor data would accurately define the damage.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Benefits of remote sensed data would result in a direct cost savings to the Federal Crop Insurance Program. Cost savings would be in the area of loss adjustment costs. These costs are presently spent on activities that are subcontracted to claims adjusters. These costs could be transferred to ERS data gathering activities.

Additional capability benefits would also result in that data on damage assessment would be readily available. Present "accuracies" in damage assessment are characterized by the following dialogue from Congressional hearings:*

ACREAGE REPORT MONITORING

MR. WHITTEN. To what extent have you monitored acreage reports for 1974 to make certain that these acreages have been correctly identified?

MR. PETERSON. Each year when the form for reporting their acreage is mailed to them, insurees are given instructions regarding the practices insured in their county and how to enter the different practices on

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* Agriculture--Environmental and Consumer Protection Appropriations for 1975 Pt. 2--House of Representatives, pp. 572-6.

the form. Generally they file accurate reports. We do conduct a limited, random spot check on the accuracy of the reporting in each county. Economy does not permit excessive monitoring of these reports, nor would it be justified by the instances of intentional inaccurate reporting.

MR. WHITTEN. To what extent will loss adjusters be able to accurately identify these acreages in the process of adjusting losses on the 1974 crop?

MR. PETERSON. We contemplate no difficulty in determining whether the practice reported has been followed. This is and has been a basic responsibility of the adjuster along with determination that good farming practices have been followed on the insured acreage. For acreage reported as summer fallow the adjuster usually can determine whether or not a crop was grown on the acreage the previous year. If he cannot make the determination or the insured will not admit that the acreage was not summer fallowed, verification can be made by reference to FCIC acreage reports for the previous year of ASCS records on 1973 Plantings.

MR. WHITTEN. To what extent do you spot-check loss adjustments made by local adjusters?

MR. PETERSON. Overall, the Corporation spot-checks the adjusters' work on about 5 percent of loss claims processed. Each adjuster performing work is spot-checked at least once, and more frequently depending upon his volume of work and the variety of commodities he is dealing with.

Current ERTS Activities

The following are presently funded ERTS activities in this area:

1) "Crop Inventory--Stress Detection--Land Use in Spain" GSFC ID 1623A-FO01A-C-000

2) "Gypsy Moth Investigations" GSFC ID 1679A-AGOIG-C-000

3) "Detection of Plant Disease & Nutrient Deficiencies" GSFC ID 1139A-UNOID-C-A-000

4) "Study of Wheat, Phenology, Vigor, Pests, Diseases & Yield" GSFC ID 1569A-F001A-C-000

Estimate of ERTS Economic Capability

Quantifiable ERS economic capability would result from equal capability cost saving benefits to the Federal Crop Insurance Program. Gross benefits of ERS data on agricultural crop damage assessment can replace at least half of FCIC's loss adjustment budget, thus providing at least $1.31 million annually in equal capability benefits. No additional ERTS data over what is needed for RMF's 1.1 and 1.6.1-3 are needed for this RMF.

Significant non-quantifiable benefits would result from more accurate assessment and compensation for crop damage.

Annual Benefits:
Equal capability $1.31 million

RMF No. 1.7.1

REDUCTION OF DAMAGE TO AGRICULTURAL CROPS DUE TO MASSIVE UNEXPECTED INSECT OR DISEASE INFESTATION

Rationale for Benefits

Massive outbreaks of insect and disease infestation in crops are not easily predictable. Extensive crop losses occur when slow detection allows outbreaks to become widespread before they are noticed. Wheat rust epidemics in 1935, 1937 and 1953 resulted in losses upward of 50% of the crop; heavy damages were also inflicted by the more recen outbreak of Southern Corn Leaf Blight. Reductions in the losses can be achieved with earlier and more accurate detection of outbreaks and their extent.

Non-Federal Activities

A number of universities have initiated pilot programs utilizing "detector plots" of various crops, which are closely monitored for any disease outbreaks or insect infestations. Among these are a corn blight monitoring program and a soybean disease monitoring program at the University of Missouri.

The Function of Remote Sensing

Remotely sensed data may provide continuing and useful information on the status of insect and disease infested areas, and can provide unique early warning of potential outbreaks, since disease or insect stresses may be remotely sensed before they are visible to the naked eye.

Estimate of ERTS Economic Capability

Anderson*, in testimony before the House Appropriations Committee, estimated that a non remote-sensed early detection program for disease alone could reduce annual crop losses due to disease from 15 to 10%. This would yield an annual benefit of approximately $2.5 billion.

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* Axel L. Anderson, Statement before the House Subcommittee on Agricultural, Environment and Consumer Protection, in that committee's 1975 Appropriations Hearings. pp. 198 - 212.

RMF No. 1.7.1

An ERS system can, most likely, improve on the loss reduction figures for a non remote sensed system, due to continuing coverage. Taking a conservative figure of 1%, as the reduction in crop losses attainable with an ERS early warning system for disease alone, ROM benefits are estimated to be $200-500 million, once every 2-4 years as such stresses may occur.

Annual ROM benefits:

Increased capability, ($200-500 million) once every 2-4 years but not included in the totals in Table 1.

RMF No. 1.7.2

CLIMATE CHANGES AFFECTING AGRICULTURAL CROP PRODUCTION

Rationale for Benefits

Subtle changes in crop vitality and yield over large areas due to slow changes in climate have been detected. For example, climate changes seem to be taking place due to air pollution in Michigan.* These changes have resulted in slow changes in crop yield.

Early identification of such trends permits timely re-allocation, if necessary, of affected agricultural areas to different crops or other land uses, and can also indicate what new lands might become suitable for certain agricultural uses if changes continue.

Federal Government Activities and Responsibilities

The National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, is charged under 15 USC 313 with the "display of frost and cold-wave signals": and the general "distribution of meteorological information." NOAA carries on a full scale program of agricultural weather forecasts and warnings, and provides advisory weather services to users in the agricultural sector.

Functions of Remote Sensing

Remotely sensed data can be used to monitor both changes in crop vitality over time, and trends in climatic indicators. Continuously updated information, made possible with remote sensing, can yield benefits from early identification of crop vitality and climate changes over time, with which cropland reallocation decisions, if they are necessary to maintain and increase production, can be made more quickly.

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* Congressional Testimony on Pollution Monitoring Program of Charles W. Mathews, Associate Administrator for Applications, NASA, 1975.

RMF No. 1.7.2

Current ERTS Activities

Kanemasu* repoıts that ERTS data can be used to estimate soil moisture, one key climatic indicator, through estimates of crop vigor. An ERS system with thermal IR band can, in addition, measure surface temperature, assuming 50% cloud cover or less, within about 1°C,** or better.

Another promising area is the use of vegetation systems as indicators of regional climatic changes. Rouse*** has used ERTS data on vegetation areas of the Great Plains as an indicator of regional drought and other weather patterns.

Estimate of ERTS Economic Capabilities

There are no easily quantifiable present benefits realizable with an ERS system. Benefits, some rather substantial, are likely to accrue over time in specific instances where the monitoring of ERTS data results in the detection of regional climatic trends, as has already happened in western Michigan. Benefits will increase more quickly if northern hemisphere climatic changes continue and more serious weather problems result for farm producers.

Annual Benefits:

Not estimated (possibly substantial)

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* E. T. Kanemasu, Kansas Environmental and Resource Study: A Great Plains Model, Wheat: Its Water Use, Production and Disease Detection and Prediction, Kansas State University, February 5, 1974.

** Useful Applications of Earth-Oriented Satellites - Meteorology #4, National Academy of Sciences, 1969.

*** Rouse, "Monitoring the Vernal Advancement and Retrogradation (green wave effect) of Natural Vegetation," The Use of the Earth Resources Technology Satellite (ERTS) for Crop Production Forecasts, Task Force on Agricultural Forecasting, July 24, 1974.

RMF No. 1.7.3

UNIQUE INTERNATIONAL TRADE EVENTS

Rationale for Benefits

Timely and accurate information on worldwide grain production is necessary if international trade is to be undertaken at the proper time, and if the volume of trade is to be at the most beneficial level. Benefits accrue to U.S. producers and consumers, who may be spared the consequences of price fluctuations resulting from trade agreements made without adequate information.

Functions of Remote Sensing

Remote sensing provides new capabilities for widespread gathering of agricultural data necessary for accurate worldwide forecasts of yield and production.

Estimate of ERTS Economic Capability

The wheat sale agreement between the U.S. and U.S.S.R., made in 1973, was followed by a sharp rise in U.S. wheat prices, from about $2.50/bu in July 1973 to about $4.50/bu in September 1973.* The total volume sold in this transaction was about 11.7 million metric tons. Assuming that better information about the 1973 U.S.S.R. wheat crop shortfall would have lead U.S. to sell at $4.50/bu, the value lost to the U.S. as a result of sales made at $2.50/bu is $865.8 million.** With the more realistic assumption that the sale would have been made, with better information, at $3.50/bu, value lost to the U.S. is $432.9 million. While an elimination of this value loss, due to ERS crop production forecasts, represents only a one-time benefit, events of this type are likely to recur, perhaps on an every two-to-four year basis.

Annual ROM Benefits: ($200-500 million)
new capability, once every 2 - 4 years,
but not included in the totals in Table 1.

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* D. B. Wood. The Use of the Earth Resources Technology Satellite for Crop Production Forecasts: Task Force on Agricultural Forecasts, GSFC, 1974, p. 13.

** The approximate conversion of 37 bushels = 1 metric ton is used.

RMF No. 1.8.1

MONITOR NEW AGRICULTURAL PRACTICES

Rationale for Benefits

Experiments in agricultural practices require detailed monitoring at both the individual plant level and over the entire experimental region. Continuous monitoring of crop growth and vitality is required to evaluate new practices aimed at improving crop strains; timely information is needed to assess the impact of these practices and of variations in their application.

Federal Government Activities and Responsibilities

The Agricultural Research Service of the Department of Agriculture is responsible for overseeing Federal research activities, pursuant to 7 USC 427, 427i. Its FY 1974 estimated expenditures are $124M in farm research and $10M for research in the eradication of narcotic producing plants.

Functions of Remote Sensing

Remote sensing can be useful in monitoring the progress of agricultural experiments, providing, with repeated passes, records of changes in condition of both experimental and control areas. Mc.e specifically, wide-area coverage of repercussions of new practices or experiments can be monitored more easily and accurately with remote sensed data.

Current ERTS Activities

ERTS principal investigator for this area is:

Charles W. Bouchillon
Mississippi State University
P.O. Drawer GH
State College, Mississippi 39762
601-325-4825

Dr. Bouchillon is presently investigating possible applications of ERTS to the monitoring of agricultural practices in Mississippi.

Estimate of ERTS Economic Capabilities

It does not appear that an ERS can yield any quantifiable benefits in this area. While ERS imagery may be useful as a tool for monitoring the progress of certain

RMF No. 1.8.1

experiments, or for estimating the extent of, say, new trends in uses or types of fertilizer, such benefits are difficult to estimate. One possible benefit of an established ERS system might be overall lower costs for agricultural research, made possible by readily available and nearly continuous remote sensed data, for use in monitoring experiments or new agricultural practices.

Annual Benefits:

Small

RMF No. 1.8.2

MONITORING REMEDIAL ACTIONS TAKEN IN AREAS SUBJECT TO CLIMATOLOGICAL AND SOIL CHANGES

Rationale for Benefits

Soil conservation measures are of prime importance in maintaining agricultural productive capacity; every year substantial losses from wind and water erosion are sustained by farm operators and land owners (see RMF 1.5.1). Just as important, however, is continuous monitoring of these conservation measures and remedial actions -- both their progress and degree of success -- as well as any changes in optimal land use patterns which may be indicated because of changing conditions.

Federal Government Activities and Responsibilities

Federal government activities in this area fall under the jurisdiction of the Soil Conservation Service, USDA, and are described in RMF 1.1.3. Of particular significance is the "Land Inventory and Monitoring Program" described in that section.

Function of Remote Sensing

Remote sensed data can give timely, wide-area coverage and allow continuous monitoring of project status. Unexpected repercussions can be quickly identified and appropriate measures taken. Cost savings can also be realized in any program where project personnel presently make on-site inspections of the effectiveness of control measures, and where remote sensed data could be used instead for the same purposes.

Estimate of ERTS Economic Capabilities

Benefits for this RMF, specifically those from new capabilities for monitoring the progress of remedial actions, overlap with those related to the long-term "Land Inventory and Monitoring Program", described in RMF 1.1.3, and with the shorter term benefits of soil conservation measures described in RMF 1.5.1. No benefits, then, will be claimed under this RMF.

Annual Benefits:

See RMF's 1.1.3 and 1.5.1

RMF No. 1.9.1

MONITOR COMPLIANCE WITH FEDERAL AND LOCAL AGRICULTURAL REGULATIONS

Rationale for Benefits

Benefits can result from reduced costs for compliance checks of agriculture regulations. The largest savings should be realized where fairly comprehensive, or even 100 percent, inspections of critical areas are necessary, as in, for example, pest control programs. Effective enforcement of regulations can substantially increase the overall success of infestation control efforts which lead to increased production, and yield benefits to farm operators and consumers particularly during periods of tight supply. See RMF's 1.6.1 and 1.6.2.

Non-Federal Activities

The California State Department of Agriculture has established specific planting and plowdown dates for the state cotton crop, in an effort to arrest the progress of the pink bollworm, which has adverse effects on crop yield and quality. Strict enforcement of plowdown deadlines can eliminate the food supply, made up largely of plant material remaining after picking, which is necessary for development of bollworm larvae. Extensive enforcement efforts, however, are necessary for a successful control program. At present all crop area identification and mapping is done by ground survey, and department personnel are responsible for periodic checks of compliance.

Functions of Remote Sensing

Compliance checks and crop identification can be accomplished with remote sensing at reduced cost, with significant manpower savings. The timeliness of remote sensed data facilitates early identification of violators, thus contributing to the success of regulatory programs.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

A model along the lines of that proposed in RMF 1.9.2 would be appropriate for estimating cost savings in compliance checks; the acreage distribution given in Figure 9 can also be applied to the total acreage in the California bollworm control project (80,000 acres). Unfortunately, cost breakdowns for enforcement by field size are not available.

Coleman et. al.* (see section on Current ERTS Activities), however, give total costs for crop identification and field condition both for field survey methods and for the use of remote sensed data; these figures are given in Table 17.

Current ERTS Activities

ERTS principal investigator in this area is:

Lowell N. Lewis
Citrus Research Center
Agricultural Experiment Station
University of California
Riverside, California 92502
714-787-3106

Table 17 Cost Estimates of ERTS-1 Investigation and Agricultural Commissioners Field Surveys

Valley	Man Hours		Cost, dollars	
	ERTS-1	Ag. Comm.	ERTS-1	Ag. Comm.
Imperial	161	320	$ 846.00	$1,800.00
Coachella	15	120	90.00	600.00
Palo Verde	15	+	90.00	+
Total	191	440	$1,026.00	$2,400.00

\+ Data Unavailable
Source: Coleman, et.al., Evaluation of Remote Sensing in Control of Pink Bollworm in Cotton, NASA Contract No. NAS5-21771, Final Report, March, 1974.

*V.B. Coleman, C.W. Johnson and L.N. Lewis, Evaluation of Remote Sensing in Control of Pink Bollworm in Cotton. NASA Contract No. NAS5-21771, Final Report, March, 1974.

RMF No. 1.9.1

Coleman et. al.* have reported 97% accuracy, after four ERTS passes, in discerning field condition (bare, wet, plowed, harvested, or cropped) for 90,000 acres of cotton in three southern California valleys: Imperial, Coachella, and Palo Verde. Crop identification accuracies for this study ranged from 82% for sugar beets to 63% for cotton, the investigators blame these low figures on the short amount of time allotted for the study, and expect that accuracy would have been substantially higher if full year coverage had been available to them. These capabilities for distinguishing field condition and for crop identification suggest that both the crop mapping and compliance check activities of the California Department of Agriculture, with respect to control of pink bollworm in cotton, can be supplemented and eventually replaced by the use of ERS imagery.

Estimate of ERTS Economic Capabilities

Table 17 gives total cost figures both for present California Department of Agriculture survey activities in the three bollworm infested valleys, and for the investigators' surveys using ERTS imagery. Four ERTS passes were involved. With the incomplete data for Palo Verde Valley removed, the table shows a 61% cost reduction with the use of ERTS. This percentage figure breaks down to an 85% cost reduction for the Coachella Valley, and a 53% reduction for the larger Imperial Valley, suggesting that the advantages of ERTS investigations are even greater for smaller regions, where smaller farm sizes may result in relatively higher costs for ground survey inspections.

Assuming that agricultural commissioners' costs are the same for the Palo Verde Valley as for the Coachella (again see Table 17), total cost for ground surveys is $3,000. Since the cost of an ERTS investigation for the same area is $1,026, annual benefits for this project alone are taken to be $2,000.

Annual Benefits:

Equal capability, $2,000

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* V.B. Coleman, C.W. Johnson and L.N. Lewis, Evaluation of Remote Sensing in Control of Pink Bollworm in Cotton. NASA Contract No. NAS5-21771, Final Report, March, 1974.

RMF No. 1.9.2

MONITOR COMPLIANCE WITH FEDERAL FARM INCOME STABILIZATION PROGRAMS

Rationale for Benefits

On site inspection for compliance with acreage allotments, undertaken for all farms participating in Federal income stabilization programs, represents a major investment in time and manpower. Cost savings can result from a reduction in the number of necessary farm visits; also, manpower resources can be freed for other tasks.

Federal Government Activities and Responsibilities

The Agricultural Stabilization and Conservation Service, USDA, is charged with the enforcement of provisions of the Agricultural Adjustment Act of 1938, as amended, dealing with acreage allotments for cotton, feed grains, wheat, tobacco, peanuts, and rice. The Service collects necessary data from regular farm visits and from spot checks, and compiles acreage reports. Some aerial photography is used for checking compliance. An estimated 400,000 man-days will be required for checks on compliance and compilation of reports in FY 75; the Service reports an average cost per man year for these tasks of $12,000. Total yearly costs for compliance, then, are about $20 million.

The Function of Remote Sensing

Remote sensing allows reduced costs for all aspects of ASCS enforcement operations. Specifically, the need for actual visits to farms can be substantially reduced. Records of official acreage allotments and farm operator reports of acreage planted can serve as truth data; visits to farms, then, need only be made in those cases where remote sensed data have brought farmer compliance into doubt.

Economic and Technical Models for Estimating Benefits of Remote Sensed Data

Proposed is a model which estimates benefits from the elimination of farms visits for checking compliance. The model gives cost savings from reduced man days as a function of the minimum acreage field for which remote sensed data can be used in compliance checks (see Figure 9), and is based on ASCS reports of man-day allocations.

RMF No. 1.9.2

The distribution of acreage harvested by size of plot harvested is given in Figure 9. Thus, for example, 10% of acreage harvested is grown on plots of 50 acres or less. This information is used to estimate the percentage of ASCS acreage measurement functions which can be assumed by remote sensing.

Current ERTS Activities

Refer to RMF 1.2.1 for a description of recent ERTS activities in crop acreage mensuration.

Estimation of ERTS Economic Capabilities

Figure 8 gives remote sensing benefits as a function of the smallest acreage field for which remote sensing can be used to check compliance. The estimated benefit from use of an ERS system to replace farm visits, at the present limits of ERTS resolution, is $1.5 million.

ASCS reports an estimated 371, 557 man-days expended for acreage measurements and compliance spot checks in FY 1975, making total annual expenditures in this area approximately $17.9 million. Assuming that ERS data can be used successfully on all fields of 80 acres or greater (a conservative estimate), about 80 percent of crop acreage can be checked by ERS (see Figure 9. Thus, the cost saving to ASCS from use of ERS imagery for acreage measurements and compliance spot checks is taken to be $14.3 million. When combined with the benefits from reduced compliance check farm visits estimated to be $1.5 million (Figure 8), this gives a total benefit of $15.8 million.

Annual Benefits:

Equal capability ($15.8 million)

RMF No. 1.9.2

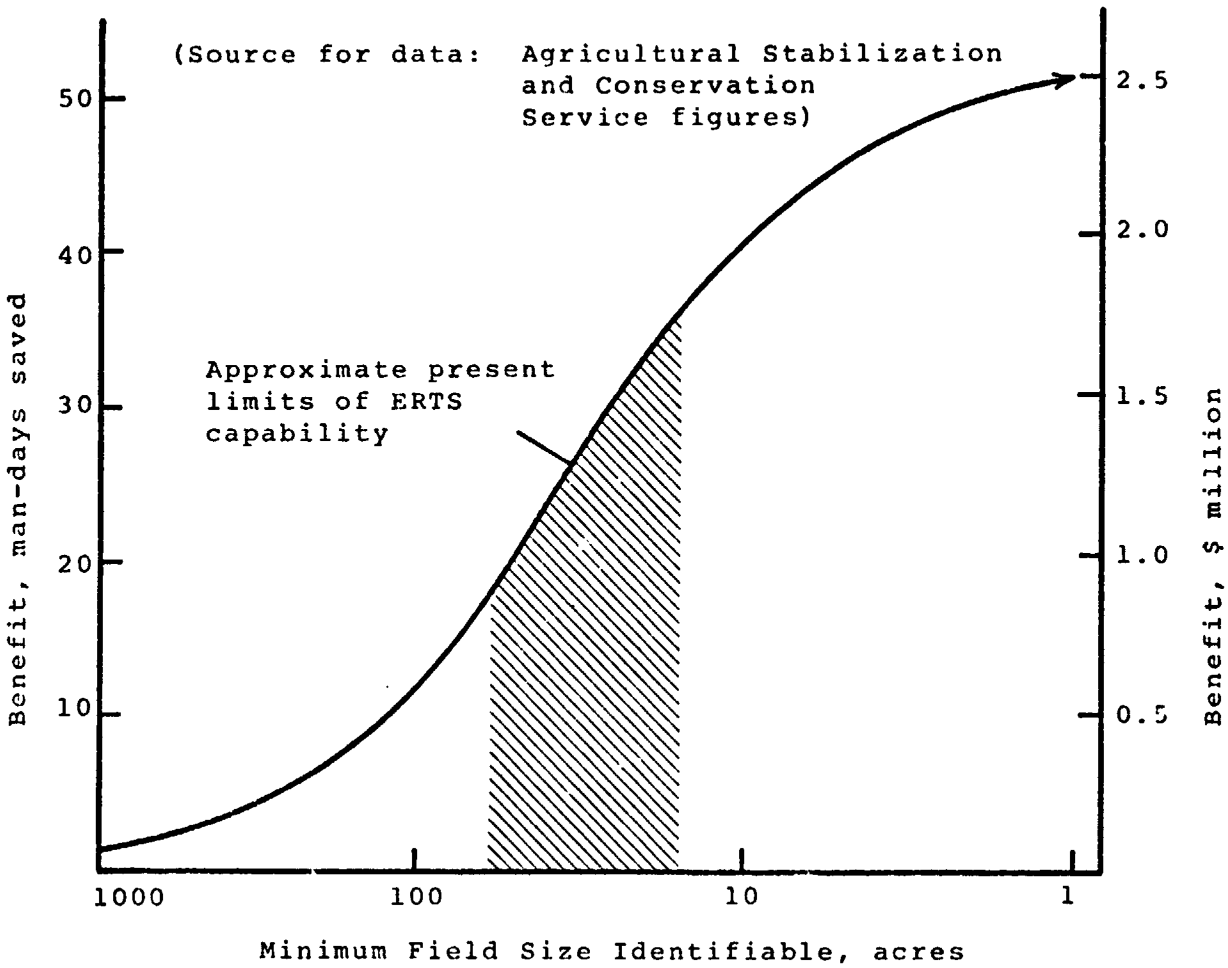

Figure 8 Benefit in Reduced Man-Days of Farm Visits From Remote Sensed Compliance Checks of Farm Income Stabilization Programs

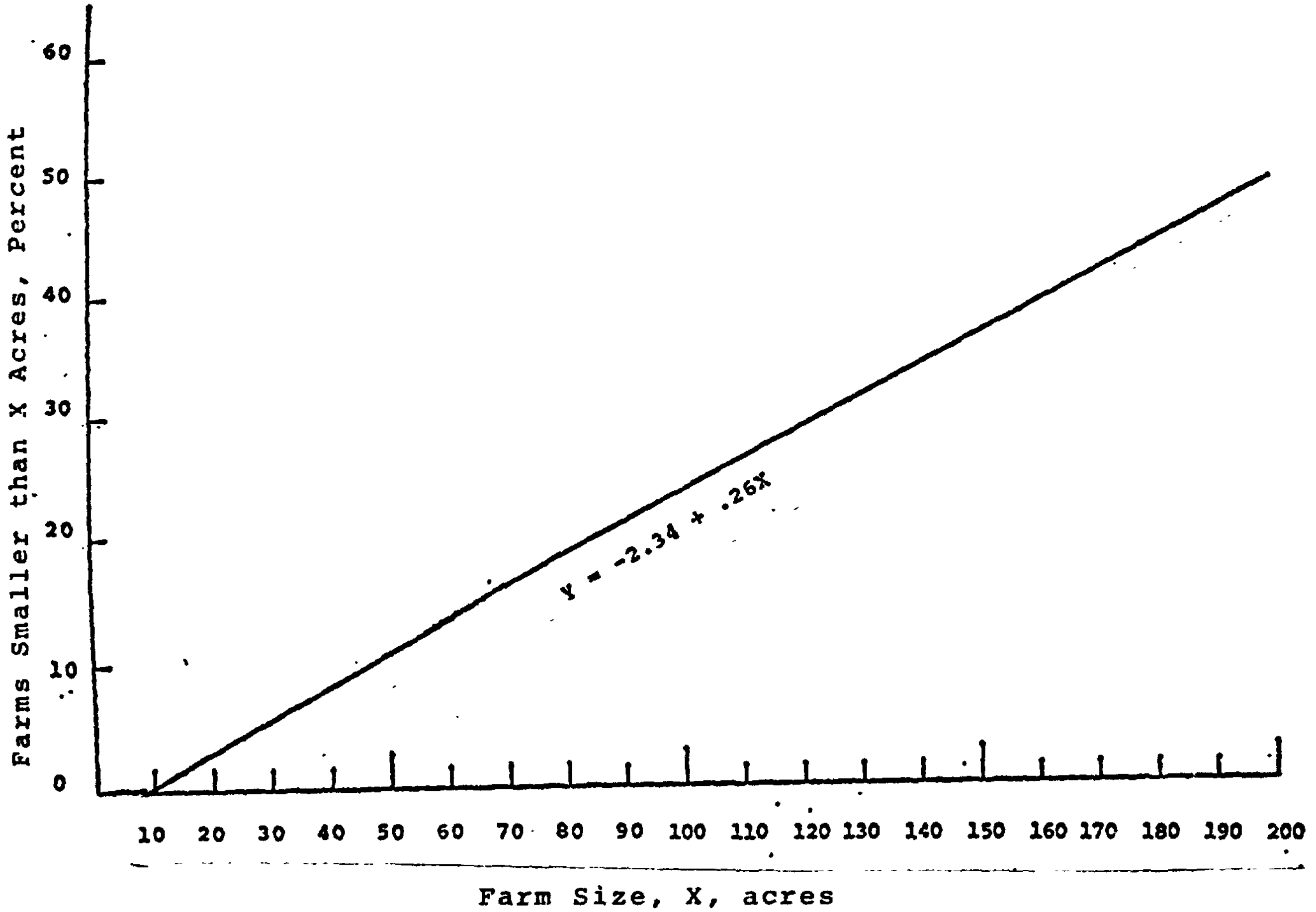

Figure 9 Cumulative Percentage of Total Cropland by Size of Field Harvested

Source: U.S. Census of Agriculture, 1959.

APPENDIX B:

SUMMARY OF APPLICABLE FEDERAL BUDGETS

Table 18 lists federal budget appropriations for FY 1975, applicable to each RMF. Where figures are for other than FY 1975, the year listed is the latest for which the necessary breakdown of allocations by specific activity is available.

Table 10 Summary of Applicable Federal Budgets* - Intensive Use of Living Resources: Agriculture

Resource Management Function	Federal Agency**	Budget Allocations, $ millions
1.1 Cartography, Thematic Maps and Visual Displays		
1.1.1 Worldwide Survey of Agricultural Land		none
1.1.2 Thematic Mapping by Crop Type and Soil Type	SCS	3.6(FY1973)
1.1.3 Domestic Soil Surveys	SCS	35.5
1.1.4 Monitor Agricultural Land Use Change		none
1.1.5 Pest and Weed Surveys	APHIS	1.54
1.2 Statistical Surveys		
1.2.1 Domestic Crop Acreage and Yield Measurements: Distribution Effects	SRS	26.1
1.2.2 Worldwide Acreage and Yield Measurements: Distribution Effects	FAS	8.3
1.2.3 Livestock Inventories	SRS	2.0(FY1973)
1.3 Calendars		
1.3.1 Optimize Planting Schedules		none
1.3.2 Optimize Harvesting Schedules		none
1.3.3 Determine Regional Cyclical Pest and Insect Infestations		none
1.4 Allocation		
1.4.1 Allocation of Agricultural Land to Specific Crops		none
1.4.2 Allocation of Stock Breeding Areas		none
1.5 Conservation		
1.5.1 Soil Conservation	SCS	162
1.6 Damage Prevention and Assessment		
1.6.1 Agricultural Crop Disease Prevention	APHIS	46.3
1.6.2 Agricultural Crop Insect Infestation Prevention	APHIS	
1.6.3 Agricultural Crop Weed Infestation Prevention		none
1.6.4 Agricultural Crop Stress Prevention		none
1.6.5 Assessment of Damage to Agricultural Crops Due to Disease, Insects and Weed Infestation, Stress, Frost and Other Weather Phenomena	FCIC	2.62
1.7 Unique Event Recognition and Early Warning		
1.7.1 Reduction of Damage to Agricultural Crops Due to Massive Insect or Disease Infestation		none
1.7.2 Climate Changes Affecting Agricultural Crop Production		none
1.7.3 Unique International Trade Events		none
1.8 Research		
1.8.1 Monitor New Agricultural Practices	ARS	134
1.8.2 Monitor Remedial Actions Taken in Areas Subject to Climatological and Soil Changes	SCS	see 1.1.3
1.9 Administrative, Judicial and Legislative		
1.9.1 Monitor Compliance with Federal and Local Agricultural Regulations		none
1.9.2 Monitor Compliance with Federal Farm Income Stabilization Programs	ASCS	20

* FY1975 Budget unless otherwise noted

** Abbreviations for agencies of USDA:

- APHIS Animal and Plant Health Inspection Service
- ARS Agricultural Research Services
- ASCS Agricultural Stabilization and Conservation Service
- FAS Foreign Agricultural Service
- FCIC Federal Crop Insurance Corporation
- SCS Soil Conservation Service
- SRS Statistical Reporting Service

Source: The Budget of the United States Government, Fiscal year 1975

APPENDIX C:

SUMMARY OF APPLICABLE LAWS AND STATUTES

Laws and statutes applicable to each RMF are listed in Table 19. Refer to individual RMF reports in Appendix A for more detailed information on specific laws and statutes, and on applications of remote sensing to each statutory requirement.

Table 19 Summary of Applicable Laws and Statutes - Intensive Use of Living Resources: Agriculture

Resource Management Function	Applicable Laws and Statutes
1.1 Cartography, Thematic Maps and Visual Displays	
1.1.1 Worldwide Survey of Agricultural Land	
1.1.2 Thematic Mapping By Crop Type and Soil Type	42 USC 3272, 16 USC 590
1.1.3 Domestic Soil Surveys	43 USC 315f, 43 USC 1181
1.1.4 Monitor Agricultural Land Use Change	7 USC 1010
1.1.5 Pest and Weed Surveys	7 USC 1652
1.2 Statistical Surveys	
1.2.1 Domestic Crop Acreage and Yield Measurements: Distribution Effects	7 USC 411a,b; 92-331; 89-321 7 USC 1622
1.2.2 Worldwide Acreage and Yield Measurements: Distribution Effects	7 USC 1761
1.2.3 Livestock Inventories	7 USC 1622
1.3 Calendars	
1.3.1 Optimize Planting Schedules	
1.3.2 Optimize Harvesting Schedules	7 USC 147a
1.3.3 Determine Regional Cyclical Pest and Insect Infestations	
1.4 Allocation	
1.4.1 Allocation of Agricultural Land to Specific Crops	7 USC 1344. 7 USC 1358, 7 USC 427. 427i
1.4.2 Allocation of Stock Breeding Areas	
1.5 Conservation	
1.5.1 Soil Conservation	16 USC 590. 7 USC 1010. 7 USC 427. 427i, PL 92-419
1.6 Damage Prevention and Assessment	
1.6.1 Agricultural Crop Disease Prevention	7 USC 147a
1.6.2 Agricultural Crop Insect Infestation Prevention	7 USC 147a, 7 USC 145
1.6.3 Agricultural Crop Weed Infestation Prevention	7 USC 1652
1.6.4 Agricultural Crop Stress Prevention	
1.6.5 Assessment of Damage to Agricultural Crops due to Disease, Insects and Weed Infestation, Stress, Frost and Other Weather Phenomena	7 USC 1652, 7 USC 147a
1.7 Unique Event Recognitiona and Early Warning	
1.7.1 Reduction of Damage to Agricultural Crops Due to Massive Insect or Disease Infestation	7 USC 147a
1.7.2 Climate Changes Affecting Agricultural Crop Production	15 USC 313
1.7.3 Unique International Trade Events	
1.8 Research	
1.8.1 Monitor New Agricultural Practices	7 USC 427, 427i
1.8.2 Monitor Remedial Actions Taken in Areas Subject to Climatological and Soil Changes	
1.9 Administrative, Judicial and Legislative	
1.9.1 Monitor Compliance with Federal and Local Agricultural Regulations	Agricultural Code of California Section 3595
1.9.2 Monitor Compliance with Federal Farm Income Stabilization Programs	PL 89-321

APPENDIX D:

ESTIMATION OF THE INCREMENTAL COST OF ERS IMAGERY

The cost of data products depends primarily upon the type of item which is requested. In some cases simple photographic processing might suffice while in others detailed rectification and interpretation are necessary. For agricultural statistic requirements, cost estimates are based on the use of the GSFC ERTS data handling facilities and in particular the GSFC LACIP facility which is to be operational within a year. This facility will have automated (digital) rectification and interpretation equipment and will provide 24 hour turn-around capability from the time of data reception to its dissemination. Two possibilities are investigated: rental option and the purchase option.*

Rental Option

Based on the present cost of ERTS-1 imagery, the cost of ERS imagery assuming rental of facilities is as follows:

a)	Cost of ERTS scene (raw data)	$ 225	each
b)	Processing costs (15 min @$400/hr)	100	each
c)	Cost of rectification	100	each
d)	Personnel costs for processing (3 times processing costs) and rectification costs	600	each
e)	Classification costs**	1,625	each
		$2,640	each

* Numbers are based on D.B. Woods, The Use of The Earth Resources Technology Satellite for Crop Production Forecasts, GSFC, 1974.

** Estimated from Christie, R. "The Value of ERTS in the Establishment and Updating of a Nationwide Land Cover Information System," ECON Inc. August 15, 1974.

Since each ERTS frame covers 35,000 km^2 then the cost of ERTS imagery per square kilometer is:

Cost of ERTS images/km^2 = \$.0757/km^2 (Rental Option)

Purchase Option

In costing the purchase option, the Federal Republic of Germany medium-scale analog/digital facility is used as a model. The non-recurring costs are made up of the following*

Facility (5000 ft^2)	\$125,000
Basic System (including analog/digital subsystem integration)	200,000
Software Development	20,000
Antenna	300,000
	\$645,000

The recurring annual costs are (per ERS scene based on 320 scenes/year)

ERS Scenes	\$ 225
Rectification	100
Operating Expenses	38
Full Time Operating Staff (Salary and overhead of 1 scientist, 2 operators/technicians and 1 supervisor)	312
Classification Costs	1,625
per scene	\$ 2,300

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* D.B. Woods, "The Uses of ERTS for Crop Production Forecasts, GSFC, 1974.

At a 10% depreciation rate, with the processing of 320 scenes per year, the non-recurring costs become $202 per scene; therefore the total cost per scene in the purchase option is $2,310 per scene or on a per km^2 basis:

$$\text{Cost of ERS images/km}^2 = \$.066/\text{km}^2.$$

Calculations in the text use the higher of the two values, namely the $.0757/$km^2$ of the rental option.

APPENDIX E:

ROUGH ORDER OF MAGNITUDE MODEL FOR ESTIMATING BENEFITS OF IMPROVED AGRICULTURE CROP STATISTICS

The theory of net social benefits of statistical reporting developed by Hayami and Peterson* is based on Alfred Marshall's** social welfare and social cost concepts where social costs, or opportunity costs, are defined as the area under the supply curve.

Hayami and Peterson point out that under the assumption of rational profit and utility maximization behavior by producers, marketing firms and consumers, a sampling of error in statistical reporting of the production or the stock of commodities can be expected to lead to a net decrease in social value. Erroneous information causes producers to make production decisions and also distort optimal inventory carryovers. Hence, marginal improvements in the accuracy of these statistics reduces the social cost of misinformation, which is therefore net social welfare.

By making the further assumption that production cannot be altered significantly in response to output predictions, but where the inventory holders are able to adjust stocks, Hayami and Peterson sketch out a theoretical framework for estimating benefits of improved statistical information. The above assumptions are valid in the area of agricultural crops in that once the crops are planted, it is usually not profitable for producers to significantly expand or contract the output. On the other hand, it is relatively easy and inexpensive to store the commodities or release them from storage. In this case any market supply adjustment is possible mainly through adjustments in inventory.

Losses to the public in general due to errors in production forecasts arise because of distortions from the optimum consumption pattern of the products. Because products of this type are produced during a relatively short period of time within the year, their consumption patterns depend very much on the inventory policy of marketing firms. Expectations

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* Hayami, Y., and Peterson, W., "Social Return to Public Information Services: Statistical Reporting of U.S. Farm Commodities", American Economic Review, March, 1972, p. 120.

** Marshall, A., Principles of Economics, Eighth Edition, London, 1916.

of a small crop in the forthcoming period leads to higher prices and reduced inventory depletion during the current period. If production responses to a price change can be considered to be perfectly inelastic during the production period, then if the crop yield turns out to be greater than expected, the inventory surplus that will be created in the forthcoming period will require a higher inventory depletion rate through lower prices. The economic losses to the public as a result of such production forecast errors are discussed below and are referred to as the ECON Rough Order of Magnitude Model (ECON ROM Model).

Suppose the statistical reporting agency estimates the current period production as Q' as opposed to the actual or "true" production Q*, see Figure 9. Inventory holders, in forming price expectations for the coming period, expect the average price to equal P'. In other words, they would expect the future price to be higher by P'-P* than would be the case had no error been involved in the production estimate. Consequently, inventory holders find it profitable to decrease their rate of inventory depletion for the remainder of the year, until current price has risen to P'. Consumption then would reduce to Q', or by the amount Q*-Q'. In turn, the

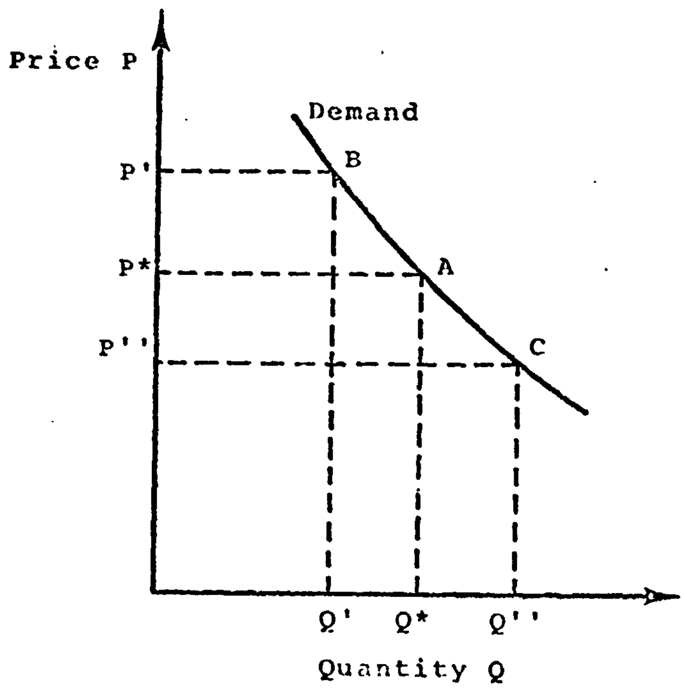

Figure 10 Price-Quantity Demand Curve for Agriculture Crops

inventory carryover into the next production period would be increased by the same amount. As a consequence, the reduction in consumption during the current period would reduce the economic benefit by the area ABQ'Q*.

Because of the abnormally large carryover into the next period, (Q*-Q') the next period's supply would increase by the amount Q*-Q' to a value of Q"=2Q*-Q', which represents the total quantity placed on the market during the next period, i.e., the "true" production Q* plus the increased carryover Q*-Q'. The result would be a decrease in the average price down to P" as opposed to price P which would have prevailed had there been no reporting errors. The decrease in price, however, results in an increase in consumption during the next period by the amount Q*-Q'. Thus, the total economic benefit is increased during the next period by ACQ"Q*.

The overall result of reporting errors that gave rise to the decline in current consumption and the increase in future consumption is a net loss in economic benefit which equals the area ABQ'Q* minus area ACQ"Q* in Figure 10.

Hayami-Peterson assumed a linear demand curve of slope dP/dQ. Let a be the price elasticity of demand, $a=dQ/Q \cdot P/dP$ and ε represent the ratio (Q*-Q')/Q* (or the percent error in the forecasts/100) then the net loss in public benefit is given by

$$\text{Net loss in public benefit} = \varepsilon^2 P^* Q \frac{1}{a} \qquad \text{(E-1)}$$

where Q* is the true quantity of production, P* is the equilibrium price. Net public benefits are obtained by in fact reducing the net public loss by reducing the error estimate from the present ε_o to a lower value ε_{ERS}. The Net Public Benefit NPB of improved information is then

$$NPB = \frac{P^*Q^*}{\alpha^*} \left(\varepsilon_o^2 - \varepsilon_{ERS}^2\right)$$

Because of the highly price-demand inelastic nature of agricultural products the assumption of linearity of the demand curve within the error estimates of production is not valid. In many cases the linearity assumption leads to negative values of P". To alleviate this problem, the ECON ROM Model considers both exponential and constant elasticity forms of the demand curve. Assuming the price P^* and elasticity a^*, the Net Public Benefit using the exponential model is given by

$$NPB = 2P^*Q^*a^* \cosh(\varepsilon_{ERS}/a^*) - \cosh(\varepsilon_o/a^*)) \qquad (E-2)$$

where the form of the demand curve is

$$P = P^*e^{-a^*(Q/Q^*-1)} \qquad (E-3)$$

In the constant elasticity model the demand curve is expressed by

$$P = P^* \left(\frac{Q^*}{Q}\right)^{1/a} \qquad (E-4)$$

and the net social benefit is

$$NPB = \frac{P^*Q^*}{\beta} \quad (1 + \varepsilon_{ERS})^{\beta} + (1 - \varepsilon_{ERS})^{\beta} -$$
$$(1 + \varepsilon_o)^{\beta} - (1 - \varepsilon_o)^{\beta}$$

where $\beta = (a - 1)/a$ (E-5)