12

ECONOMIC ANALYSIS IN THE PACIFIC NORTHWEST LAND RESOURCES PROJECT: THEORETICAL CONSIDERATIONS AND PRELIMINARY RESULTS

D. R. A. Morse* and J. T. Sahlberg+

National Aeronautics and Space Administration,
Ames Research Center, Moffett Field, California

and

Bureau of State Planning and Community Affairs,
Boise, Idaho

Abstract

The Pacific Northwest Land Resources Inventory Demonstration Project is an attempt to combine a whole spectrum of heterogeneous geographic, institutional and applications elements in a synergistic approach to the evaluation of remote sensing techniques. This diversity is the prime motivating factor behind a theoretical investigation of alternative economic analysis procedures. For a multitude of reasons--simplicity, ease of understanding, financial constraints and credibility, among others--cost-effectiveness emerges as the most practical tool for conducting such evaluation determinations in the Pacific Northwest. Preliminary findings in two water resource application areas suggest, in conformity with most published studies, that Landsat-aided data collection methods enjoy substantial cost advantages over alternative techniques. The potential for sensitivity analysis based on cost/accuracy tradeoffs is considered on a theoretical plane in the absence of current accuracy figures concerning the Landsat-aided approach.

---

*Ph.D. Candidate, Department of Economics, University of California, Berkeley, and Independent Contractor, Economic Studies, PNW Project, NASA/Ames.

+Economist in the Bureau of State Planning's Division of Budget, Policy Planning and Coordination.

The authors wish to thank Kim Johnson, University of Idaho, Dewayne McAndrew and Alan Robertson, Idaho Department of Water Resources, and Bud Bartels and Larry Jebousek, Oregon Water Resources Department, for providing data and information on which parts of the paper are based.

Introduction

In the fall of 1974, a need for more accurate and current natural resource and land use information upon which to base planning activities and management decisions was expressed by the Pacific Northwest Regional Commission (PNRC). The Commission, one of seven multi-state organizations created and funded pursuant to Title V of the Public Works and Economic Development Act of 1965, believed that the establishment of a source of data that would be both reliable and continuous was essential to the functioning of the Washington, Oregon and Idaho state governments.

In light of this need, the Commission discussed the concept of remote sensing and formed the Land Resources Inventory Task Force (LRITF) to investigate the possibilities for operational utilization of this tool (including both its prospective benefits and costs) in the Pacific Northwest. Fruitful discussions between the LRITF and representatives of the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) combined with strong "user agency" interest in the tri-state area led to the birth of the Pacific Northwest Land Resources Inventory Demonstration Project (PNW Project).

The project, a three year venture scheduled for completion in early 1978, involves the cooperative interaction of more that 35 state and local agencies and over 100 personnel from diverse fields of interest. Moreover, the project is broad in scope--exploring potential applications of remote sensing in a number of disciplines including forestry, agriculture, rangeland, urban development, weeds monitoring, water resources, land use, and surface mining.

The diversity of the participants naturally brings a variety of motivations. The PNRC objective is to promote the economic development and stability of the Northwest region. The NASA/Ames goal is the operational utilization of Landsat data and imagery products in a cost-effective manner. Finally, user agencies are interested in finding cheaper and better methods for collecting data of improved quality, consistency, reliability and scope.

However, despite their differing objectives, if user agencies in the Pacific Northwest are to utilize Landsat data on an operational basis, the primary justification for such a move must be an economic one. Certainly social, institutional, legal and moral factors must be considered. Nevertheless, if a Landsat-aided system can not prove its worth from a dollars and cents perspective, it has no chance and no justification for being approved by the budget analysts.

Consequently, this paper is directed to an examination of the economic aspects of the PNW Project. In what follows, we hope to analyze the problem from a theoretical point of view, delineate and justify the methodology for economic analysis that we have chosen, and present and discuss some of the initial numerical results.

PACIFIC NORTHWEST PROJECT

User Agency Motivations, Budgets and Data Requirements

An important consideration in the Pacific Northwest Project which impinges upon the type of economic analysis that should be pursued, concerns the nature of user agency involvement. The motivation for their participation seems to be one of perceived "necessity" rather than a desire to evaluate alternative systems on an economic basis or determine if a new technology can yield benefits over and above costs. In most cases, the participating agencies find themselves combating vastly expanding tasks with relatively constant budgets in the face of rising costs. As they see it, they simply must find a cheaper way to conduct their business. This belief has created a situation in which many user agencies feel that there are no meaningful and feasible alternatives to a Landsat-aided data collection system. In the words of Dennis Issacson, Oregon Department of Agriculture, in order to locate and monitor the spread of the noxious Tansy Ragwort weed "...we need to have complete coverage of the state of Oregon. Landsat is currently the only source of such imagery. For effective control, we need at least four complete coverages each year. With our current resources this coverage is impossible to obtain." Consequently, "Landsat technology provides a cost-effective way to do many of the jobs we currently are assigned...assists us in doing a more effective job for the dollars we expend...and provides the only way we could currently attempt to locate and control Tansy on a statewide basis."[1]

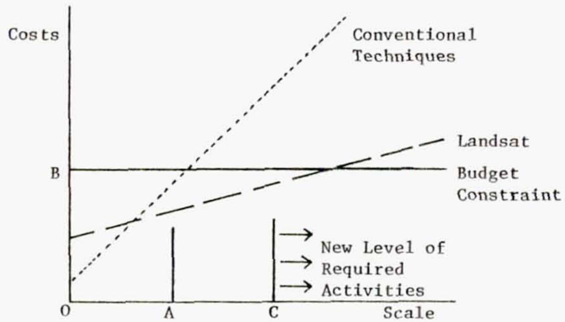
For this reason, many of the user agencies are not particularly interested in any type of economic analysis. Their attitude is simply, *Tell us the costs of the Landsat-aided system, then we'll decide for ourselves within the context of our own budget constrictions if, and to what extent, we can afford to utilize it.* This outlook is combined, in many cases, with a justifiable distrust of federal agencies in general (based on past attempts to impose a technology from above) and of economic (most especially cost-benefit) analyses in particular (due to the plethora of studies of debatable validity). Hence, the task of choosing an appropriate form of economic analysis valuable as a guide to rational action and acceptable to the user agencies is indeed difficult. This is an important consideration and a matter to which we shall subsequently return.

The real impetus in the search for more cost-effective data collection methods is the barrage of new state legislation that was passed in the late 1960's and early 1970's as a result of growing awareness of environmental and ecological problems. Many user agencies in the Pacific Northwest find that they are required to greatly enlarge the scope of their activities as a result of this new legislation. The Department of Natural Resources of the state of

Washington, for instance, has until recently been responsible for managing two and one half million acres of state lands. However, under the terms of the Forest Practices Act of 1974, they are now required to oversee 10 million acres of productive commercial forest lands in Western Washington and an additional 10 million forested acres statewide. To do this on a relatively fixed budget is clearly an imposing problem. Nevertheless, this is typical of the situation faced by many of the user agencies in the Pacific Northwest. How Landsat data might help solve their present predicament is perhaps best summarized in Fig. 1.

Conventional data gathering techniques are labor intensive and, therefore, characterized by small "up front" or fixed costs and relatively proportional (and steep) increases as a function of area or size. Landsat-aided methods, on the other hand, involve greater initial outlays but smaller per unit increases as the level of activity expands (since they are more capital intensive). User agencies were previously operating in the range OA which posed no problems in terms of their budget constraint OB. As long as agencies could meet their requirements using conventional approaches, they had no incentive to change.

The new legislative requirements have changed all this. User agencies now find themselves with expanded responsibilities and the need to operate at a much larger scale, say OC or greater in Fig. 1. The implications of this increased legislative burden are readily apparent. Firstly, user agencies can not possibly hope to carry out this scale of activities by utilizing conventional tech-



Cost-Scale Tradeoffs of Landsat and Conventional Techniques
Figure 1

niques--they are much too expensive and budget limitations absolutely preclude their use. Secondly, with the growth in the level of operations, Landsat techniques may not only be cheaper than conventional methods, but may be the only currently known process by which user agencies can hope to discharge their duties and still stay within their budget constraints.

Clearly, as soon as the level of agency operations expands much beyond OA, current techniques for information acquisition must be curtailed and replaced or supplemented by cheaper alternatives. This is, at least on a theoretical level, an explanation of user agencies' search for and interest in a new technology that has the potential to allow them to do that which they currently have no other financially feasible method of doing. But, what implications does the introduction of Landsat data gathering techniques have for user agencies, and how do we evaluate their impact from an economic point of view?

Evaluation Techniques

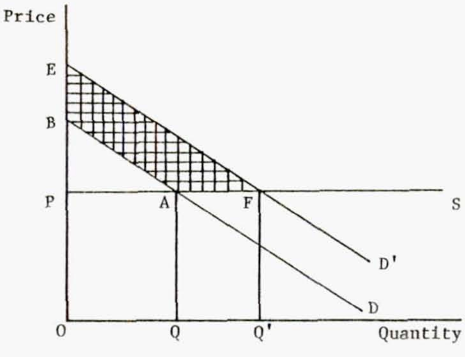
There are four circumstances under which the Landsat approach can demonstrate its economic value. Firstly, in the absence of an alternative system for attempting to do the same job, Landsat must still be able to yield dollar benefits over and above operating costs. Secondly, given the existence of a competing alternative system, Landsat may be able to do the job more cheaply with a comparable level of accuracy. Thirdly, the Landsat-aided system, while costing the same as the "next best" alternative system, might produce more or better quality products with greater accuracy and/or cover a larger area. Finally, even if it is more expensive, the Landsat-aided system might yield substantially more benefits and, hence, have a better benefit/cost ratio than competing alternatives.

Other questions certainly need to be asked and may well impinge upon the decision regarding the ultimate utilization of Landsat data on an operational basis by agencies in the Pacific Northwest. Paramount among these considerations are the potential sources and amounts of agency funding, the distribution of benefits, the institutional, social and legal impacts on agencies and their workers of changing to a new system, and so on. However, it is apparent that an economic evaluation of the new Landsat technology should be the prime objective. Such an evaluation generally takes one of two forms--a cost-benefit or a cost-effectiveness analysis.

Cost-Benefit Analyses

In conducting a cost-benefit analysis, the objective is to determine what projected benefits will result from a given investment or course of action, what the costs of the activity will be, and, hence, what differential or net social benefit will result. There are two very tricky points in the analysis--specifying the likely benefits and expressing both them and anticipated costs in common (dollar) units. The theoretical underpinnings of cost-benefit analyses are to be found in the economist's concepts of supply, demand, consumer surplus, alternative cost, and willingness-to-pay. Although a demand and supply analysis can only lead to a partial equilibrium solution (since secondary, tertiary and subsequent repercussions throughout the economy are not accounted for), this is the best simple guide to rational public expenditure that is available, and, hence, it is to a consideration of these matters that we will now direct attention.

Benefits resulting from the use of Landsat data can be attributed, at least in part, to an improvement in the quality of information. In the case of the Department of Natural Resources (DNR) of the state of Washington, for instance, economic benefits resulting from improved stocking, commercial thinning and harvesting decisions are the direct result of better (more accurate, more timely, etc.) information on timber location, condition, specie class and so on. If we use a simple demand and supply diagram, we can represent the demand curve for information on the part of the DNR before the introduction of Landsat technology by, say, D in Fig. 2. The area OPAQ represents the cost and the total price paid for this quantity of information. PBA is the consumer sur-



Cost-Benefit Estimation of Net Social Benefit
Figure 2

plus--the benefit to society which is not paid for due to uniform pricing practices. The entire area under the demand curve, OBAQ, represents the total welfare to society of the provision of OQ units of information and, hence, indicates the total amount society would be willing-to-pay.

Now improved information commands a higher price because it yields increased societal benefits. Consequently, the demand curve shifts out to, say, D'. Assuming, for simplicity of exposition, a perfectly elastic supply curve, S, price stays constant at OP but the quantity of information "purchased" increases to OQ'. Costs of production and, hence, total expenditure are represented by the area OPFQ', consumer surplus is PEF, and willingness-to-pay, the total benefit of this information to society, increases to OEFQ'. Therefore, the gross benefit to society (the increased willingness-to-pay) from the introduction of Landsat technology is the area QABEFQ', and the net benefit is ABEF, the increase in consumer surplus.

The above constitutes a theoretical approach to the problem of benefit estimation for the purpose of evaluating the dollar impact of a new technology in a particular area. In actual fact, such an analysis will not yield quantitative estimates because of the difficulties associated with attempting to determine the shape, location, and movements of both the demand and supply curves. It is useful, however, to establish the nature of the problem and to show both the subtleties and complexities inherent in it.

The ability to obtain a quantitative benefit estimate and the faith that can be attached to it varies from case-to-case. It depends both on the nature of the problem studied and the skill and experience of the analyst in the assumptions made, the proxy variables utilized, and the surrogate prices chosen. Some general observations can be made, however. The primary advantage of a cost-benefit analysis is that it provides a guide to action when no other information exists. It does not require the existence of a comparable alternative system against which to evaluate the one under consideration. Rather, it is most suited to those situations where no real alternative exists or where the system being evaluated yields returns (benefits) not attainable in other ways. On the negative side, the quantification of benefits is a highly questionable operation in the absence of competitive market prices (as is the case for social goods). Consequently, the impact of a cost-benefit analysis is always limited by the nature of the assumptions made and the shaddow prices chosen. Such an analysis can seldom be definitive--it is always open to serious question and challenge and, hence, may be dismissed by many people on the grounds that it can be manipulated in the hands of a skillful and experienced practitioner to "prove" either side of an issue.

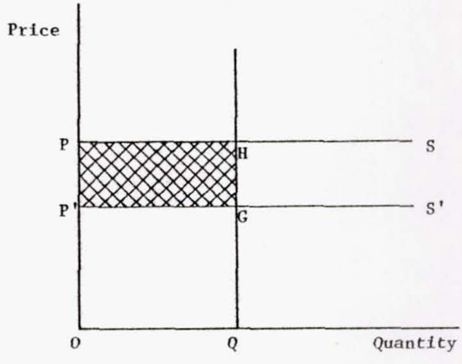
Cost Effectiveness Analyses

A cost-effectiveness analysis is a particular type of cost-benefit analysis whose objective is to compare the costs of two different systems in generating the same information or end products. This alternative cost approach to benefit estimation can be analysed graphically, as was the cost-benefit technique. Consider Figure 3.

We will continue to assume a perfectly elastic information supply curve. In addition, we will now add the assumption of a perfectly inelastic demand curve for information. This is a very convenient situation since it means that we do not have to consider benefits resulting from improved quality information (when the demand curve shifts, it moves vertically and is therefore unchanged). It is only appropriate, though, firstly, when we are evaluating two systems which yield comparatively identical outputs and, secondly, when one of the systems is certain to be undertaken in the absence of the other (which, admittedly, begs the issue as to whether either system can yield benefits over and above costs). Under these circumstances, with the original supply curve, S, OQ "units" of information will be produced at a total cost of OPHQ. The introduction of Landsat may lower per unit costs to OP', as the supply curve shifts to S', thereby decreasing total costs to OP'GQ. Since production costs are a minimum bound for the value of output, the net benefit to society is at least as great as the ensuing cost differential, P'PHG.

As in the cost-benefit analysis, this presents only a theoretical approach to the problem of benefit estimation. But, in this case, quantitative measures of the magnitude of the benefit are easier to obtain. As before, we make no attempt to derive the actual demand or supply curves--they are merely the logical justification for our procedure. Rather, it is simply a matter of using actual market prices to compute the cost for each of the two competing alternative systems of producing the same quantity of (assumed to be identical) output. As in theory, the cost differential provides an easily obtained numerical measure of net social benefit.

The primary advantage of a cost-effectiveness analysis is that it utilizes real market prices to "cost out" well-defined systems. Consequently, it is relatively easy to undertake, replicable, and believable. However, that does not mean that there are no difficulties with such an analysis. Clearly, to evaluate a given system against the "next best" alternative system requires that we know what that alternative system is. This is not a terribly serious problem, for either the system already exists and is

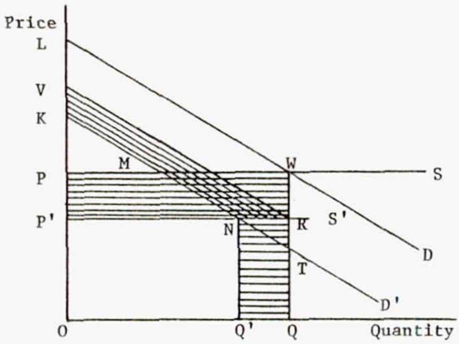


Cost-Effectiveness Estimation of Net Social Benefit
Figure 3

in current use, or it can be determined without too much difficulty by considering the known possibilities. However, there are two major stumbling blocks.

Firstly, as alluded to above, in the absence of a cost-benefit analysis, there is nothing to "prove" that either system can yield benefits over and above costs. The two systems are evaluated relative to one another; conceivably, they could both be inefficient in an absolute sense. This is why a cost-effectiveness analysis is only justifiable in situations where one system is certain to be undertaken (for legislative reasons or otherwise) in the absence of the other. Secondly, the two systems must be virtually identical in terms of output products if the magnitude of the cost savings is to be representative of the net social benefit. This is not a trivial requirement as will be demonstrated below.

Consider Figure 4. We retain the horizontal supply curves (for simplicity only) but, to allow for different quality products, return to the assumption of a negatively sloped demand curve. Let D and S be the demand and supply curves, respectively, for the "without Landsat" system. Equilibrium implies the procurement of OQ units at per unit price OP involving total costs OPWQ and yielding gross benefits OLWQ and net benefits PLW. Suppose, now that the "with Landsat" system lowers per unit costs to OP', reflected



Cost-Effectiveness Estimation with Non-Equivalent Systems
Figure 4

in a shift in the supply curve to S'. Obviously, if Landsat can yield better quality products, we would not need to go further--improved output at lower prices would make it the preferable system. So, for the purpose of the analysis, let us assume that the Landsat-aided system leads to fewer or less accurate output products. This would be reflected in a shift in the demand curve (to say D') towards the origin indicating a decline in willingness-to-pay and, hence, social welfare. Equilibrium is at point N, wherein OQ' units are acquired at per unit costs of OP' leading to total costs of OP'NQ', gross benefits of OKNQ', and net benefits of P'KN.

Which system is better? There are two parts to the analysis. From a cost-effectiveness point of view, the "with Landsat" system lowers costs from OPWQ to OP'NQ'. Hence, Landsat yields a social benefit equal to the cost differential (the horizontally shaded area)--namely, P'PWR (due to lower per unit costs) plus Q'NRQ (due to smaller output). However, it also yields a dis-benefit since consumer surplus declines from PLW to P'KN. Now triangles PLW and P'VR are identical, hence, we can express the dis-benefit as the difference between P'VR and P'KN which equals NKVR, the diagonally shaded area. Therefore, the "with Landsat" system yields both a benefit (P'PWR + Q'NRQ) and a dis-benefit (NKVR) and, while it is better that the "without Landsat" system from a strict cost point of view, in actual fact, a rational choice between the systems requires an accurate weighing of the magnitude of the benefit against that of the dis-benefit. Clearly, depending upon the amount by which the demand and supply curves shift relative to one another, the result can come out either way.

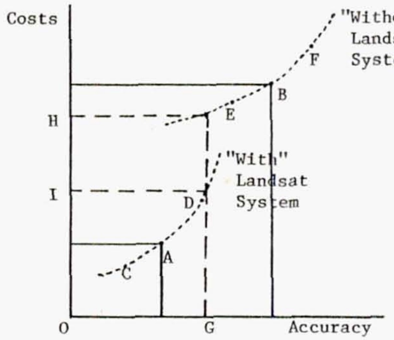
The above does not give us cause for despair, however. It does not mean that unless the systems being evaluated yield identical output products that a cost-effectiveness analysis will lead to indeterminate results. It merely complicates matters a little and gives rise to the need for a sensitivity analysis. Without delving into the mechanics of the situation, suffice it to say that, in the absence of comparable system options, an investigation of cost/accuracy tradeoffs, as in Fig. 5, allows us to choose between competing alternatives when we would not be able to choose on the basis of cost-effectiveness considerations alone (point A versus point B). Reverting to practical matters for the moment, perhaps we should point out that user agencies will be conducting this type of analysis themselves implicitly when they compare alternative systems on the basis of accuracy and cost subject to their known minimum accuracy requirements and budget constraints.

These comments conclude our investigation of economic evaluation techniques. On the basis of the above arguments, financial and manpower limitations, and our perceived attitude of user agencies towards all economic analysis, we have adopted the approach of examining one agency at a time utilizing cost-effectiveness techniques. We feel that such a procedure, while having inevitable shortcomings, is still a powerful and effective instrument with the additional advantages of being relatively simple to employ and understand, and of requiring a relatively small commitment of manpower and finances. We also believe that a cost-effectiveness analysis is more credible and less objectionable to the ultimate users and decision makers.

We now turn to an examination of this procedure in the context of two case studies for which some preliminary cost figures are available.

Case Studies

The two projects that are discussed below are both attempts to determine the extent of irrigated acreage in a river basin or valley. While similar in purpose, the studies present a nice contrast in approach in that the Snake river project involves digital analysis whereas the Klamath procedure is based solely on photo interpretation. It is encouraging to note that both of the agencies involved are keenly interested in the results of the other's study and in testing the alternative procedure in their own area.



Sensitivity Analysis
Figure 5

The Snake River (Idaho) Irrigated Lands Project

It would be difficult to overstate the importance of water to the state of Idaho. Water is the basis of Idaho's economy. It provides irrigation for agriculture, Idaho's leading and first billion dollar industry; it drives the turbines which generate hydro-electric power for Idaho's homes and industries; it is a major factor in attracting tourists (the state's third largest industry); and it is a source of recreation.

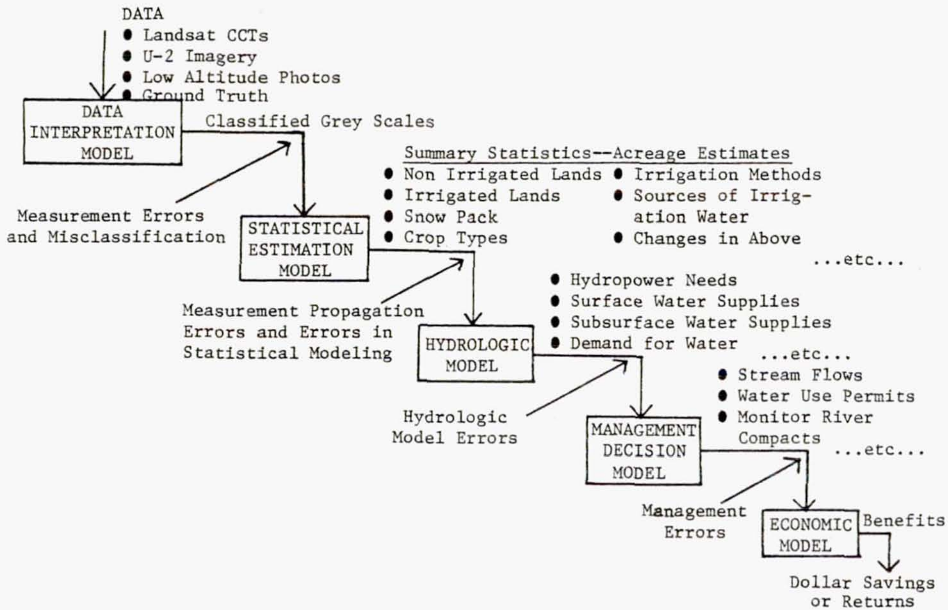
By virtue of having water resources in excess of 223 million acre feet (one acre foot equals 325,851 gallons of water), Idaho should have sufficient water to meet these often-conflicting needs. But the supply of water is not necessarily located near the demand. Southern Idaho, with the majority of irrigated lands in the state, receives less than 12 inches of rain a year, while Northern Idaho, with small amounts of irrigated or potentially-irrigable land has an average rainfall of 38.9 inches. The mountainous terrain which separates northern and southern regions precludes the transfer of water from the one to the other, which in turn makes critical the management of water supplies in areas of high demand.

Concerns about the lack of a strong, state planning organization to deal with water-related issues and about the potential diversion of part of Idaho's water to the Pacific Southwest led to the creation of the Water Resources Agency in 1964. Under executive reorganization in 1973, this agency became the Department of Water Resources (IDWR). Today, this Department has jurisdiction over all of Idaho's water, including the massive geothermal resources around the Idaho batholith, the Snake river, the main source of irrigation water in Idaho, and the aquifers which underlie much of the state. In addition, the Department is involved with regional water management with the Bear River Compact and the Pacific Northwest River Basins Commission. In more general terms, the Department is constitutionally charged to "formulate and implement a state water plan for optimum development of water resources in the public interest".

The IDWR has serious problems, however, in attempting to carry out its prescribed duties. It has developed a surface flow model of the Snake river and an aquifer model of the water running under the Snake river plane in order to simulate river flows for the purpose of water management. But one of the major input parameters to these hydrological models is the extent of irrigated acreage. Since over four million acres of irrigated lands lie along the Snake river valley, this clearly presents an imposing data collection problem. Indeed, conducting a field survey, the currently employed procedure, is extremely expensive and takes five years of concentrated effort to complete. When we allow for the fact that water rights adjudication (which, at times, involves up to 30,000 people) absorbs most of the Department's time, it is easy to understand that much of the information currently available on irrigated acreage along the Snake river is up to ten years old. Obviously, this data has very little validity as an input to the hydrological models.

The motivations for IDWR participation in the PNW project, therefore, are readily apparent. They wish to utilize Landsat data to develop estimates of irrigated acreage, methods of irrigation, sources of irrigation water and related parameters. In addition, they hope to employ Landsat data products as an aid in monitoring agreements reached under the Bear River Compact and the Pacific Northwest River Basins Commission, and in the areas of water rights adjudication and issuance of water permits.

The process by which Landsat and other data inputs are transformed into economic benefits is illustrated in the applications systems diagram of Fig. 6.[2] The three levels of data are employed in a multi-stage sampling analysis to generate estimates of irrigated acreage and so on. These are utilized as inputs to the hydrological models to provide information on water supply and demand. This guides management decisions on water release and storage, hydroelectric power generation, and the like and, hopefully, translates into net social benefits (in the form of increased returns and/or lower costs).



Snake River Irrigated Lands Project--Applications System Diagram
Figure 6

While the verbal part of our analysis deals with both costs and benefits, the numerical segment, as summarized in Table 1, is a strictly cost-effectiveness treatment. The comparisons are based on data provided in part by Kim Johnson of the University of Idaho (working in conjunction with IDWR) for an on-going study of the entire southern portion of the state. Clearly, primarily on the basis of lower photo acquisition costs, the Landsat-aided data collection system enjoys about a 3:2 cost advantage over the "next-best" alternative system of the ones evaluated.

The Klamath River Basin (Oregon) Irrigated Lands Inventory

Like the Idaho Department of Water Resources, the Oregon Water Resource Department (OWRD) has regulatory responsibility regarding water rights adjudication, issuance of water permits, and so on. In addition, they are responsible for monitoring all water resources within the state which includes 18 major river basins. A problem of immediate concern to the OWRD concerns the Klamath River Basin Compact of 1957, an agreement between the states of Oregon and California to limit the usage of water from the Klamath river watersheds to that amount sufficient to irrigate at most 200,000 acres of the Oregon Klamath river basin. If the OWRD intends to monitor irrigation activity in this area, it is clear that they require a quick and inexpensive method for inventoring the nearly 6,000 square miles in question.

Currently, the Department uses visual inspection and low altitude photography to provide its data base. However, these techniques, according to Bud Bartels and Larry Jebousek of the OWRD, "are labor intensive and are getting extremely expensive, which when coupled with our increasing data needs, make a considerable impact on our budget". They conclude, "we could not possibly inventory...our irrigated lands at the needed frequency with our current resources".[27]

To alleviate this problem, the OWRD have been working with Dr. William Draeger of the EROS Data Center in a photo-interpretive study of Landsat imagery of the Klamath river basin. An estimate of total irrigated acreage was obtained by manual delineation utilizing a dot-grid sampling system. Selected sample plots were then visited to provide ground data with which to adjust the photo-interpretation estimates. The procedure is summarized in the applications system diagram of Fig. 7.

The numerical results that we have been able to obtain comparing costs of alternative data collection systems for the Klamath river basin are presented in Table 2. This chart is based upon data provided by Bud Bartels, Larry Jebousek and Bill Draeger.

Table 1
Cost-Effectiveness Analysis--Snake River Project

Activity \ Data Collection Methods	Commercial Lear Jet	U-2 Cost Reimbursable[3]	U-2 Real Cost	Landsat
Photo Acquisition	11,775 13,150 24,925[4]	20,410 18,840 39,250[5]	39,250 18,840 58,090[6]	2,200 1,100 3,300[7]
Photo Interpretation & Acreage Determination[8]	13,544*	13,544*	13,544*	0*
Determination of Water Resource Parameters[9]				
Sampling Procedure				
a. Grid Construction[10]	947*	947*	947*	947*
b. Low Altitude Costs				
1. Aircraft[11]	2,500	2,500	2,500	2,500
2. Crew[12]	750*	750*	750*	750*
3. Pilot[13]	667*	667*	667*	667*
4. Per Diem[14]	750	750	750	750
5. Film[15]	750	750	750	750
6. Film Processing	500	500	500	500
	5,917	5,917	5,917	5,917
Ground Truth Costs[16]				
a. Wages[17]	2,472*	2,472*	2,472*	2,472*
b. Per Diem[18]	1,500	1,500	1,500	1,500
c. Travel[19]	600	600	600	600
	4,572	4,572	4,572	4,572
Sample Strip Photo Interpretation[20]	1,648*	1,648*	1,648*	1,648*
Statistical Analysis & Data Summary[21]	2,472*	2,472*	2,472*	2,472*
Digital Analysis[22]	0*	0*	0*	11,800*
(Personnel Costs)[23]	(22,500)	(22,500)	(22,500)	(20,756)
Benefits[24]	3,600	3,600	3,600	3,321
(Total Non Photo Acquisition Costs)[25]	(32,700)	(32,700)	(32,700)	(30,677)
Overhead[26]	8,175	8,175	8,175	7,669
TOTAL	65,800	80,125	98,965	41,646

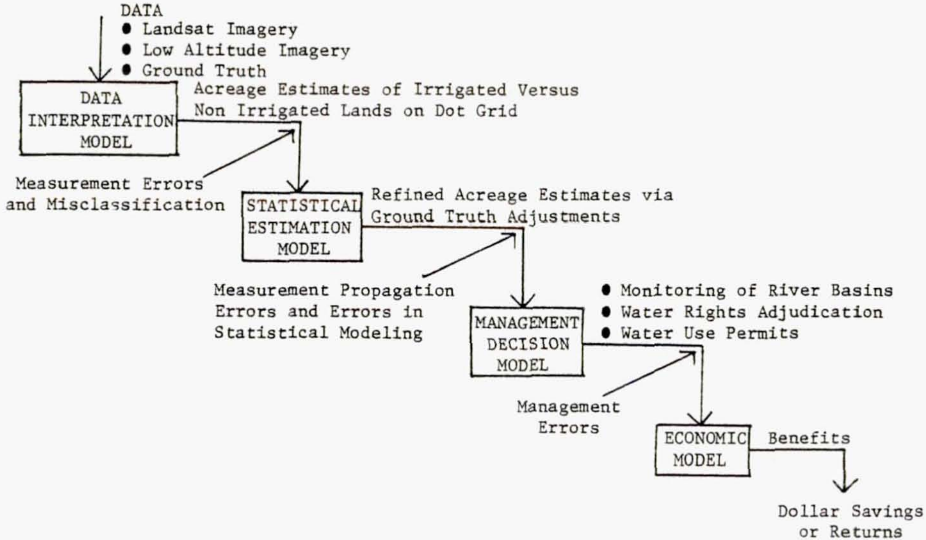
Their original figures showed a cost advantage for the Landsat system over that actually employed by the OWRD of approximately $1,500 to $20,000 (or, about 13:1). While this may well be an accurate figure, it does not represent (as the aforementioned gentlemen recognized) a comparison of comparable systems. The conventional techniques are accurate to one-tenth of an acre in 40 acres (or 99.75%). While we have no figures on the accuracy of the Landsat estimate, it would certainly not achieve this level. In addition, the present system involves mapping costs which are not part of the Landsat approach and must be removed if we hope to meaningfully compare the two systems. Finally, to achieve a more meaningful comparison of "competing alternative" systems, we added a third system, that based on low altitude photography, in the belief that it would prove to be more cost-effective than the field survey approach.

The results still show an approximately 2:1 cost advantage for the Landsat-aided system over the "next-best" alternative of the systems evaluated.

Analysis of Results

The results suggest that the Landsat-aided data collection techniques have significant potential in the area of cost savings over alternative systems. We have presented no accuracy figures because none are available at this juncture. Certainly that is an area which requires careful scrutiny. Indeed, the level of accuracy attained will be one of the major variables to be investigated upon completion of the projects. However, in both cases under study here, the Landsat figures are an improvement over what was previously available--10 year old data in many parts of the Idaho area and virtually no reliable data at all for some areas in the Oregon case. The only accuracy figures which are currently available, those for the Oregon Reservoir Volume Estimation Project (for which we, unfortunately, have no cost data), are all in the 98% and up range. That is not to suggest that such figures are the norm, but merely to make the case that Landsat techniques have proved to be highly accurate in some areas.

It is important to keep in mind that the cost figures that we have generated do not take account of satellite capital costs. To do so would certainly reduce or eliminate the cost advantages enjoyed by the Landsat-aided system. Our reason for doing this is that no reliable method for weighting and apportioning such costs has been developed. In order to allocate them in a meaningful way, it is essential to consider all potential cost-effective uses of Landsat data, many of which are unknown at the present time. Thus,



Klamath River Basin Irrigated Lands Inventory--Application System Diagram
Figure 7

Table 2

Cost-Effectiveness Analysis--Klamath River Basin Project

Activity \ Data Collection Methods	Field Surveys	Low Altitude	Landsat
Photo Acquisition[28]	0	1,200	360
Photo Interpretation[29]	0*	1,545*	433*
Low Altitude (Backup) Costs[30]	0	0	240
Ground Truth Costs[31]			
a. Wages[32]	3,747*	335*	335*
b. Per Diem[33]	2,250	200	200
c. Travel[34]	1,080	181	181
	7,070	716	716
Data Summary[35]	0	618	206
(Map Making)[36]	(7,000)	(0)	(0)
(Personnel Costs)[37]	(3,747)	(2,498)	(974)
Benefits[38]	600	400	156
(Total Non Photo) (Acquisition Costs)[39]	(7,677)	(3,279)	(1,751)
Overhead[40]	1,919	820	438
TOTAL	9,596 (16,596)	5,299	2,549

we have adopted the standard procedure of not taking account of these costs, leaving those that would investigate cost-benefit aspects of an operational satellite system as a whole (rather than a particular application) to worry about them.

It is interesting and encouraging to note that the cost comparisons that we have made are comparable to those obtained in other studies. In a summary document investigating state uses of satellite remote sensing in a variety of areas, Sally Bay et al, for instance, found that Landsat techniques enjoyed about an 8:5 cost advantage over low altitude photo interpretation studies.[41]

Conclusion

The results that we have obtained are very preliminary but heartening. The various demonstrations within the PNW project are still on-going and accuracy and firmer cost data must await their completion. However, even at this early stage, it seems safe to say that Landsat-aided data collection techniques hold the prospect of lower costs, better and more timely coverage, and, hence, increased social benefits.

PACIFIC NORTHWEST PROJECT

References and Footnotes

[1]Personal Interview with Dennis Issacson, May, 1976.

[2]The applications system diagram was developed by the Earth Satellite Corporation and the Booz-Allen Applied Research Corporation in their "Earth Resources Survey Benefit-Cost Study" for the U.S. Department of the Interior (Contract #135-19, Nov. 22, 1974, in particular, Volume V, pp. I-21-I-23).

[3]Cost-reimbursable system does not include maintenance and overhead costs

[4]Assuming 5,548 linear miles to be flown at 400 m.p.h. average speed at 85% flight efficiency

Collection costs = 15.7hrs. x $750/hr. = $11,775
Photo products cost = 1,315 fms. x $10/fm. = $13,150
Total cost = $24,925

[5]Assumes same swath width, speed, and, hence, linear mileage as for commercial lear jet

Collection costs = 15.7hrs. x $1,300/hr. = $20,410
Photo costs = 15.7hrs. x $1,200/hr. = $18,840
Total cost = $39,250

[6]Same assumptions as footnote 3 except that real costs are felt to be about $2,500/hr. while photo costs are kept constant at $1,200/hr. (both estimates provided by Earl D. Knechtel and Roger D. Arno, Applications Aircraft and Future Programs Office, NASA/ Ames Research Center)

Collection costs = 15.7hrs. x $2,500/hr. = $39,250
Photo costs = 15.7hrs. x $1,200/hr. = 18,840
Total costs = $58,090

[7]Does not make any provision for capital costs associated with the satellite

CCT cost = 11tapes x $200/tape = $2,200
Photo costs = 11scenes x $100/scene = $1,100

[8]For Landsat system, costs are included in digital analysis figure For other systems:

Costs = 2hrs./fm. x 1,315fms. x $5.15/hr. = $13,544

[9]The same costs were atributed to all systems (although Landsat, with its broader view, is generally felt to be cheaper) in order to ensure that alternative systems are judged in the best light.

[10]184hrs. x $5.15/hr. = $947

[11]50hrs. x $50/hr. = $2,500

[12]2men x 80hrs./man x $4.69/hr. = $750

[13]80hrs. x $8.35/hr. = $667

[14]30days x $25/day = $750

[15]10rolls x $75/role = $750

[16]Same costs attributed to all systems--see footnote #9

[17]480 hrs. x $5.15/hr. = $2,472

[18]60days x $25/day = $1,500

[19]4,000miles x $0.15/mile = $600

[20]320hrs. x $5.15/hr. = $1,648

[21]480hrs. x $5.15/hr. = $2,472

[22]None required for photo interpretive studies. One man year assumed (at Idaho wage rates) for Landsat system.

[23]All asterisked items

[24]16% of personnel costs

[25]Costs on which to base overhead

[26]25% of all operating costs

[27]Bud Bartels and Larry Jebousek, Personal Interview, May, 1976.

[28]Low Altitude: 300photos x $4.00/photo = $1,200
Landsat: 4photos x $90/photo = $360 (prints are $50 if already generated)
No provision made for satellite capital costs

[29]2men x 150photos/man x 1photo/hr. x $5.15/hr. = $1,545
2men x 42hrs./man x $5.15/hr. = $433

PACIFIC NORTHWEST PROJECT

[30]Field Survey: Costs included inphoto acquisition and interpretation figures
Landsat: 20photos x $12/photo = $240

[31]Assumes same costs for Low Altitude and Landsat systems

[32]Field Survey: 2men x 364hrs./man x $5.15/hr. = $3,747
Others: 65hrs. x $5.15/hr. = $335

[33]Field Survey: 2men x 45days/man x $25/day = $2,250
Others: 8days x $25/day = $200

[34]Field Survey: 7200miles x $0.15/mile = $1,080
Others: 1205miles x $0.15/mile = $181

[35]120hrs. x $5.15/hr. = $618
Landsat system, due to larger scope and smaller number of photos used, rated at 33% of low altitude system cost

[36]Utilized only in the actual Oregon Water Resources Department System

[37]Summation of all asterisked items

[38]16% of personnel costs

[39]All costs except photo acquisition and overhead

[40]25% of all non photo acquisition costs

[41]Sally M. Bay et al., On State Use of Satellite Remote Sensing, Denver, Colorado, August 25, 1976, pp. 44-5.