A Benefit Cost Analysis of a Soil Erosion Control Program for the Northern Watershed of Lake Chicot, Arkansas

MSC-001

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COVER PICTURE

The photograph on the cover was taken on the northern basin of Lake Chicot.

ACKNOWLEDGEMENT

Soil Erosion Control Program for the Northern Watershed of Lake Chicot, Arkansas

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Lake Chicot, a 5,025-acre oxbow lake created by the ancient meandering of the Mississippi River, is located near the town of Lake Village in Chicot County of southeastern Arkansas (Fig. 1). Today the lake is separated into a northern basin of 1,154 acres and a southern basin of 3,871 acres by a levee maintained by the Arkansas Game and Fish Commission (Fig. 2). The entire lake once offered excellent fishing and recreational benefits. But with channelization in the drainage basin and final closure of the Cypress Creek gap along the Mississippi River levee in 1920, drainage and flood waters from approximately 350 square miles of agricultural lands were diverted into Connerly Bayou and thus, ultimately, into Lake Chicot.

Feeling that the entire lake would become too polluted to support recreation, the Arkansas Game and Fish Commission constructed the existing levee across the lake just above the point at which Connerly Bayou enters. This restricted the Bayou's silt-laden input to only a portion (the southern basin) of the overall lake. The resulting impact on the southern basin was to increase greatly its silt content, turbidity, and pesticide load, and drastically diminish the recreational benefits that this portion of the lake was capable of providing.

By contrast, the northern basin of Lake Chicot has remained, until most recently, quite clean, and free of significant amounts of pesticides. This part of the lake has long been thought of as a quality recreational resource boasting a fine sport fishery and a beautiful state park. During the past ten years, however, users have begun to notice increasing turbidity which has been attributed to the yearly input of an estimated 32,323 tons of sediment from the surrounding 11,470-acre watershed.[2] Ninety seven percent of this sediment is produced by sheet and rill erosion from 10,190 acres of cropland within the watershed. It has been suggested that unless improved erosion control measures are implemented on the farmlands affecting the northern basin, the water quality of this portion of the lake will
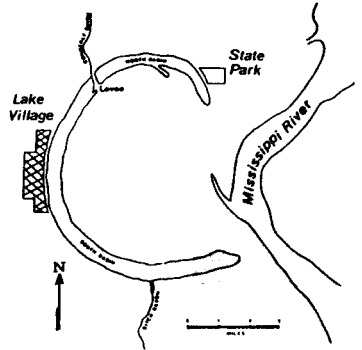
Fig. 1. General Location of Lake Chicot

Fig. 2. Local Area Map of Lake Chicot

become like that of the southern basin with a corresponding loss in recreational benefits.

The Conservation District, in cooperation with the U.S. Soil Conservation Service, is considering such an erosion control program. Their proposal, consisting of technical assistance and government subsidization, is directed toward encouraging farmers to adopt better soil conservation practices (6). Since the financing of this project would be accomplished with public monies, it is essential that the project be analyzed, at least in part, on the basis of whether or not the expected social benefits warrant the costs. If the benefit-cost ratio (b/c) is not greater than one, public investment in the project would be economically questionable. While this efficiency criterion is not the only basis upon which public projects should be judged, it nevertheless has to be of major concern to taxpayers and decision makers.

With this in mind the specific objectives of this study were to:

1) Determine the cost of reducing erosion and sedimentation under selected erosion rates in the north Lake Chicot watershed,

2) Determine the recreational benefits of erosion control associated with at least maintaining the present water quality and recreational viability of the northern basin,

3) Compare the present value of benefits to the present value of costs to determine if the proposed project can be established as an economically justifiable investment.

COST ESTIMATION PHASE

The central goal of cost estimation was to evaluate the costs associated with various erosion control plans for the north Lake Chicot watershed. This knowledge enables the decision maker to select the least cost method leading to any prescribed level of reduction. Normally one might expect that, as the desired level of erosion control increases, so too would the cost required to achieve that control.

For example, in order for a farmer to make reductions in his soil loss, he could either:

1) Employ additional erosion control practices,

2) Switch to possibly less revenue producing rotations, or

3) Let cropland return to natural vegetation if the soil loss restriction is high.

Obviously these alternatives would impose additional costs on the farmer, reducing his revenue if he were at a point of profit maximization. This lost revenue, summed for all affected farmers, serves as a measure for the social cost of erosion control[3]. However, if the farmer is not presently maximizing profit, it may be possible for him to employ erosion control practices that would not only reduce erosion, but also increase profit. In such a situation an educational program might be all that would be required to achieve the desired reduction.

Erosion Rates Resulting from Different Management Alternatives

Erosion in the north Lake Chicot watershed was determined through the use of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 8). This equation uses six physical parameters to estimate the amount of gross soil loss. The equation appears as: $A = R \times K \times LS \times P \times C$

where A = computed soil loss in tons per acre per year (TAY),

R = rainfall/runoff factor,

K = soil erodibility factor,

LS = slope length/steepness factor,

P = support practice factor,

C = cover/management factor.

The rainfall/runoff factor (R) quantifies the effect of raindrop impact and provides information on the relative amount and rate of runoff likely to be associated with the rain. The numerical value for this factor in the Lake Chicot area was determined to be 355 (8).

The soil erodibility factor (K) quantifies the natural susceptibility of different soil types to erode. Although the Soil Survey for the cropland of Chicot County indicates that nine soil types are present in the study area, with respect to the USLE they can be grouped into three main categories: 1) clay soils with a K factor of 0.24 (5,184 acres); 2) loam soils having a K factor of 0.32 (1,137 acres); and 3) loam soils with a K factor of 0.37 (3,869 acres).

Topographic considerations affecting erosion rate, essentially steepness and length of slope, are combined for convenience into one factor (LS). Within the study area, topography is relatively uniform with an average slope of 0.25 and an average length of slope equaling 250 feet, yielding LS value of 0.09.

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[3]This is valid regardless of whether or not the individual farmer actually incurs the cost of erosion control, or is subsidized by public revenues

Support practice such as contouring, stripcropping, and terracing slow water runoff and thus reduce the amount of soil the water can carry. The support practice factor (P) is the ratio of the soil loss while employing a specific support practice and the soil loss resulting from up and down slope cultivation. Effectiveness of runoff retarding practices diminishes as land slope decreases. This is essentially the case for the lands in the study area, which yield a P value of 1.0. Therefore these practices were not considered further.

The factors of the USLE presented thus far have been largely outside the control of man in reducing erosion in the north Lake Chicot watershed. The cover and management factor (C), however, can be readily altered by adopting various crop rotations in combination with different management practices, and thus serves as a major concern for this phase of the study. Essentially this factor is the ratio of soil loss from cropland under specific conditions to the corresponding loss from clean tilled, continuous fallow. Actual soil loss from cropland depends on usage of cover crops, crop sequence (rotations), management practices (fall plow, spring plow, no-till), as well as the particular stage of growth and development of the vegetative cover at the time of rain. C-values for all logical combinations of rotations and management practices were calculated using the method described by Wischmeier and Smith (8). These calculated C-values were substituted, along with the other factor values discussed above, into the USLE to estimate annual gross soil loss for all rotation-management practice combinations.

The predominant crops grown in the study area include cotton and soybeans, with significant acreage devoted to rice and wheat[4]. In 1979, rice rotations existed for clay soils only because the irrigation needed for rice production was available only to the clay soils of the watershed. Soil loss and net return calculations for the rotation-management combinations on clay soil are presented in Table 1. Table 2 summarizes this information for the loam soil of the watershed. The estimates presented in these tables represent the gross soil movement associated with various rotation-management combinations. It should be emphasized that actual sediment input to the northern basin is only some fraction of gross soil loss, since a great deal of eroded sediment is deposited in grassed and depressed areas and at the toe of the field. The calculated sediment delivery ratio for the northern basin watershed is estimated to be 0.22[5].

Linear Programming Analysis

To determine least cost strategies leading to various levels of erosion reduction, an adaptation of a whole farm planning model was employed (2). As a linear programming technique, this model's objective is to maximize farm profit before taxes (net revenues), subject to constraints upon land, labor, time, machinery, and allowable erosion. This is accomplished through the mathematical selection of

Table 1. Net Returns and Soil Loss for Each Rotation on Clay Soils
(TAY = Tons/Acre/Year)

Rotation[1]	Soil Loss (K = .24)		Net Returns	
	TAY	Rank	$/Acre	Rank
Pasture	0.1	1	7.88	29
R,S,W/S; CC & N-T	1.2	2	75.62	14
R,S,W/S; N-T	1.4	3	79.13	11
S,W/S; CC & N-T	1.5	4	52.08	27
R,S,W/S; CC	1.5	4	95.14	4
W/S	1.5	4	113.55	1
C,S,W/S; CC & N-T	1.6	7	67.36	20
R,S,W/S; SP	1.7	8	101.81	3
R,S,S; CC	1.8	9	86.51	8
S,W/S; N-T	1.8	9	48.88	28
C,S,W/S; CC	2.0	11	78.82	12
C,C,C; CC	2.0	11	54.81	25
R,S,S; SP	2.1	13	89.44	6
R,S,W/S; FP	2.2	14	103.22	2
C,S,W/S; N-T	2.3	15	69.16	19
S,S,S; CC	2.3	15	54.76	26
C,S,; CC	2.4	17	72.67	17
C,S,S; CC	2.4	17	70.03	18
C,S,W/S; SP	2.7	19	86.23	9
C,C,C; SP	2.8	20	63.49	21
S,S,S; SP	2.8	20	57.78	23
R,S,S; FP	2.9	22	89.60	5
C,S,W/S; FP	3.3	23	87.55	7
C,S; SP	3.3	23	78.40	13
C,S,S; SP	3.3	23	75.01	15
S,S,S; FP	3.5	26	57.62	24
C,S,S; FP	3.8	27	74.75	16
C,C,C; FP	4.0	28	63.23	22
C,S; FP	4.0	28	79.36	10

[1]R, Rice; C, Cotton; S, Soybean; W/S, Wheat/Soybean Double crop. FP, Fall Plow; SP, Spring Plow; CC, Cover Crop, N-T, "No-Till".

optimal and feasible rotation-management practice combinations, as outlined earlier.

Even though the watershed for the northern basin of Lake Chicot is composed of 18 farms, in part or in whole, for purposes of linear programing analysis the entire watershed (equipment complement, land, etc.) was considered as one farm. This is valid since the model does not adjust for the advantages that would be associated with economies of scale. Thus, total profit found in this manner is not significantly different from that found by evaluating each farm separately.

Because of the current lack of irrigation equipment in the watershed the model was constrained to a maximum of 160 acres of rice production each year. No-till soybeans were considered in the model only when following wheat. Weed problems in the study area associated with no-till production have severely limited its adoption.

Table 2. Net Returns and Soil Loss for Each Rotation on Loam Soils
(TAY = Tons/Acre/Year)

Rotation[1]	Soil Loss			Net Returns	
	TAY (K = .32)	(TAY (K = .37)	Rank	$/Acre	Rank
Pasture	0.1	0.1	1	7.88	21
S.W/S; CC & N-T	2.0	2.2	2	66.58	20
W/S	2.0	2.2	2	142.02	4
C,S.W/S; CC & N-T	2.1	2.4	4	95.56	15
S,W/S; N-T	2.4	2.7	5	67.77	19
C,S,W/S; CC	2.7	3.1	6	133.66	8
C,C,C; CC	2.7	3.1	6	146.55	3
S,S,S; CC	3.1	3.6	8	68.23	18
C,S.W/S; N-T	3.1	3.6	8	110.87	13
C,S,S; CC	3.2	3.7	10	110.19	14
C,S,: CC	3.2	3.7	10	127.91	10
C,S.W/S; SP	3.6	4.1	12	135.25	6
C,C,C; SP	3.7	4.3	13	158.06	2
S,S,S; SP	3.7	4.3	13	71.12	17
C,S; SP	4.4	5.1	15	133.26	9
C,S,S; SP	4.4	5.1	15	115.42	12
C,S.W/S; FP	4.4	5.1	15	135.36	5
S,S,S; FP	4.6	5.3	18	71.60	16
C,S,S; FP	5.0	5.7	19	116.21	11
C,C,C; FP	5.0	5.8	20	158.12	1
C,S; FP	5.0	5.8	20	133.67	7

[1]R, Rice; C, Cotton; S, Soybean; W/S, Wheat/Soybean Double crop. FP, Fall Plow; SP, Spring Plow; CC, Cover Crop; N-T, "No Till".

Using 1979 prices for all relevant inputs and products, plus current crop yield estimates for the different rotation-management practice combinations, 13 alternative erosion control plans were evaluated for net returns and erosion rates. Of these 13 plans, two were baseline situations: 1) the actual 1979 cropping pattern in the watershed, and 2) the cropping pattern resulting in maximum farm income. The remaining 11 alternative plans were viewed with regard to the second baseline situation.

Three of the plans considered the effectiveness of consistent cultivation practices by all watershed farmers. These included fall plow only, spring plow only, and cover crops. In the fall plow plan, the linear programming model maximized net return using only those rotations designated as "fall plow". The spring plow and cover crop plans were constrained similarly.

Three other plans assessed the impact of absolute annual soil loss restrictions on a per acre basis. Essentially, these plans simulated a direct regulation requiring farmers to reduce soil loss on each and every acre below the designated levels (5 tons per acre per year (TAY) limit, 4 TAY limit, and 3 TAY limit). Rotation-management practice combinations yielding a soil loss greater than the designated level were eliminated from consideration.

An alternative to the absolute soil loss restriction approach is an average soil loss restriction which could be enforced through a subsidy or taxing program. Here

a total soil loss limit for the entire watershed is established by multiplying the desired average soil loss per acre by the number of acres of cropland in the watershed (2.5 TAY average, 2.0 TAY average, 1.5 TAY average, and 1.0 TAY average). Under the four plans representing this concept, no rotation management practice combination was necessarily eliminated from consideration.

The final erosion control plan evaluated in the linear programming analysis was that proposed by the Soil Conservation Service. Briefly this plan calls for federal cost sharing of six best management practices (BMP s) at the levels indicated in Table 3. In addition the SCS plan encourages adoption of minimum tillage and conservation cropping systems. These practices, though, would not be eligible for federal cost sharing. However, they were considered for adoption in the model when evaluating the SCS plan.

Table 3. Soil Conservation Service "Best Management Practices" and Costs

Best management practices	Unit	No. of units	Est. unit cost
Pipe drops	Number	145	$1,088
Drop inlets	Number	5	$12,000
Filter strips	Acres	100	$80
Sediment basins	Number	2	$20,000
Grass waterways	Acres	10	$500
Cover crops	Acres/year	10,000	$21.46 rice[·]
			$17.51 soybeans[·]

[·]Cover crop cost represents the additional cost incurred by the farmer from cover crop use but does not include any indirect benefits from improved soil fertility or humus content.

Linear Programming Results

The results of modeling the north Lake Chicot watershed are presented in Table 4. Column two shows the average maximum net return per acre for each plan, while column three indicates the accompanying soil loss in tons per acre per year. The fourth and fifth columns exhibit percent reductions in net returns and soil loss, respectively, when compared to maximum possible returns (situation one). Finally column six indicates the estimated amount of sediment in tons per year entering the northern basin of Lake Chicot.[6] The Soil Conservation Service's estimate for the amount of sediment entering the northern basin in 1977 was 32,323 tons, while this study estimated that in 1979 only 9,898 tons of sediment entered the basin. Differences in the factors used in the Universal Soil Loss equation explain this large divergence. For example, the sediment delivery ratio used in this study was calculated to be 0.22, whereas the SCS developed a sediment delivery ratio of 0.42 for the entire Lake Chicot watershed and then applied this to the watershed of the northern basin. Differences in length of slope and percent slope also contribute to the divergence. The Universal Soil Loss equation factors used in this study were more specific to the northern basin watershed than those used by the SCS.

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[6]This takes into consideration gross erosion from other sources in the watershed 2148 tons per year and a sediment delivery ratio of 0.22

Table 4. Model Results

Situation	Net returns per acre	Average soil loss	Percent reduction of		Estimated sediment entering lake
			Net returns	Soil loss	
	$/acre	TAY			Tons/year
1 Max returns	107.28	3.2	-	-	7646
2 Fall plow only	106.77	3.6	.5	-14	8543
3 Spring plow only	106.28	2.9	.9	9	6974
4 Cover crop only	103.57	2.3	3.5	28	5674
5 2.5 TAY average	106.56	2.5	.7	22	6077
6 2.0 TAY average	103.12	2.0	3.9	38	4956
7 1.5 TAY average	98.83	1.5	7.9	53	3835
8 1.0 TAY average	86.88	1.0	19.0	69	2714
9 5 T/A limit	106.68	2.9	.6	9	6974
10 4 T/A limit	105.22	2.5	1.9	22	6077
11 3 T/A limit	97.54	2.6	9.1	19	6145
12 1979 actual	83.94	4.2	21.8	-31	9898
13 SCS plan	99.99	2.3	6.8	28	5539

It can be seen that the 1979 actual situation has a higher soil loss and a lower net return than the maximum return situation. Thus it would be possible not only to reduce soil loss but also to increase farm income by changing from current production practices. An intensive educational program that informs farmers about the income advantages of alternative crop rotations could achieve this end. The solution for maximum returns shows the land use in the watershed to be as follows:

1619 acres—continuous cotton; fall plow; loam soils

846 acres—cotton, soybeans; fall plow; loam soils

2122 acres—cotton, soybeans, wheat/soybeans; spring plow; loam soils

4645 acres—wheat/soybeans; clay soils

217 acres—cotton, soybeans, wheat/soybeans; fall plow; clay soils

480 acres—rice, soybeans, wheat/soybeans; fall plow; clay soils

261 acres—continuous soybeans; spring plow; clay soils

Fall plow rotations enter the maximum net returns solutions because of a limitation on the machinery complement of the study area. This limitation results in a shortage of hours available in the spring for tilling and planting, forcing the model to select some rotations that begin land preparation in the fall. Unfortunately, fall plowing leaves the land bare during the entire winter, resulting in a greater amount of erosion than does spring plowing. The machinery complement limitation is an important factor when considering the average soil loss restriction.

The information of Table 4 is graphically displayed in Figure 3 where changes in soil loss are expressed both as tons per acre per year and percent reduction from the soil loss associated with maximum returns.

Curve A in Figure 3 represents the minimum cost at which a reduction in soil loss can be achieved. This curve, composed of the average soil loss restriction plans, should be used in estimating the relevant social costs for a given level of soil loss
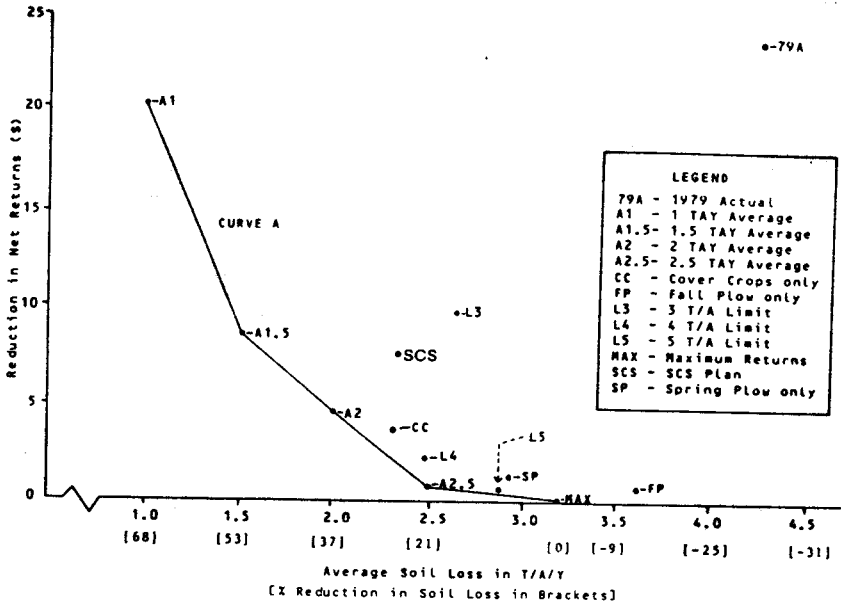
Fig. 3. Relationship between Soil Loss and Reduction in Net Returns

reduction. Points representing the various absolute soil loss restrictions also are indicated. Note that the cost of the 3-ton per acre per year limit is greater than of the 4-ton per acre per year limit with no significant decrease in soil loss.

The point representing the Soil Conservation Service proposed plan (SCS) indicates that the same amount of soil loss reduction (29%) could be accomplished at a lesser cost by initiating an average soil loss restriction.[7] The cost for the SCS plan is estimated to be approximately $356,400 over a five-year period, not including administrative costs. However only 36 percent of this expenditure is scheduled for management practices designed to control sheet and rill erosion, although sheet and rill erosion from cropland are estimated to contribute 99 percent of the sediment entering the northern basin of Lake Chicot. Field evaluation will be required to determine if federal monies used for such a plan would be cost effective.

Model results show that farmers in the study area are far from maximizing returns. Table 4 indicates that net returns could be increased by 28 percent, from $83.94/acre to $107.28/acre, by changing cropping practices. This would also result in a decrease in soil loss. Even the most restrictive situation considered, 1.0 TAY average, has a greater net return than the 1979 actual situation and results in a soil loss reduction of 76 percent.

The reason farmers in the north Lake Chicot watershed are not maximizing returns may be due to: a) a lack of information or, b) objectives other than profit

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[7]The contribution of sediment basins in the SCS plan has never been determined. Therefore, for purposes of this study their effect was assumed to be insignificant.

maximization. Such alternative management objectives may include maximizing leisure or minimizing risk. In the wheat-soybean double crop rotation, for example, net returns are high and soil loss is low; unfortunately, this rotation has a higher probability of crop failure and greater management requirements than does single cropping.

Once the maximum net returns situation has been reached, the most cost effective program for reducing soil loss would be an average soil loss restriction. This could be implemented through a per unit charge or a subsidy. A 1.5 TAY average soil loss restriction, for example, results in a 53 percent reduction in soil loss with only a 7.9 percent reduction in net returns, compared to the maximum returns situation. A 3 T/A limit, on the other hand, results in only a 21 percent reduction in soil loss with a 9.1 percent reduction in net returns.

Thus reduction in soil erosion and sediment delivery to Lake Chicot from the north Lake Chicot watershed is feasible at relatively low cost depending on the regulatory technique used to implement the program. The value of benefits to be derived from erosion control will now be examined.

BENEFIT ESTIMATION PHASE

The objective of the benefit estimation phase was to approximate the recreational benefits resulting from an erosion control program designed to at least maintain the present water quality and recreational viability of the northern basin.

It is safe to assume that in the absence of an erosion control program the water quality of the northern basin would, over time, degrade to that of the southern basin. If this were to happen it would be expected that northern basin recreational benefits also would diminish to the value of the recreational benefits derived from the southern basin. Since the main purpose of an erosion control program would be to prevent this from occurring by at least maintaining the present water quality level, the value of the benefits for the program in any particular year would be the difference between the recreational value of the northern basin in that year and the lesser value that would have occurred had the program not been undertaken. A limiting case benefit would occur at the point when the northern basin recreational value would have fallen to just equal the current recreational value of the southern basin. The magnitude of the benefit in that year would simply be the difference between the current value of the northern basin and the current value of the southern basin.

This limiting case benefit is of prime importance to this phase of the study since, once it is derived, any reasonable scenario concerning the rate at which the water quality of the northern basin would deteriorate may be used to model the flow of benefits through time as a result of program adoption. Benefits to landowners adjacent to the lake and to other potential users also may result from an erosion control program, but estimating these secondary benefits was beyond the scope of this study.

To arrive at the limiting case benefit it was necessary first to estimate the current recreational values of both basins. This is not a simple task, since outdoor public

recreation has no well defined market price. One simply cannot purchase five units of camping from the corner store as he would a multitude of other goods and services. Therefore, over the years a number of techniques have been used to deal with this nonpecuniary complication[8]. The outgrowth of these techniques, the indirect method, is presently the accepted method for estimating recreational value.

Even though outdoor public recreation has no well defined market price, it neverthless is not a costless pursuit. Recreationists do have to pay a "price" in the form of travel expenses, onsite variable expenses, token entrance fees, foregone wages, etc. The indirect approach uses these actual expenses borne by the recreationist as an indication of his willingness to pay. By observing the "price" and length of stay for a large number of recreating groups it is possible to derive an average party's demand curve for the recreational site. As the price of recreation increases we note that the quantity demand declines. From this curve it is possible to establish two different measures of recreational value.

The indirect method avoids many of the biases encountered in other value estimation techniques and is therefore the most reliable method of recreational value estimation currently available. The indirect approach, as modified by Gibbs (3) is his Klamath Lake study, was chosen for this analysis.

As stated above, two different measures of value can be derived from the demand curve established via the indirect method. The first is known as the consumer's surplus. The basic argument behind the consumer's surplus is that every consumer has a price that he would be willing to pay to avoid having to do without a certain commodity. Often the price he actually has to pay is less than the price he would have been willing to pay. The difference between these two prices is in a real sense a net benefit to that consumer. If his net benefit were added to the net benefits gained by all other consumers of the commodity, a measure of the commodity's value could be established. Since the demand curve, by definition, indicates what individuals would be willing to pay, consumer's surplus in geometric terms is merely the area above the price actually paid and below the demand curve[9]. Given this, the recreational value of each basin of Lake Chicot was found by multiplying the consumer's surplus of the average party for a visit to each basin by the respective number of basin visits per year.

While the magnitude of the consumer's surplus is expressed in monetary units, this value is not involved in exchange and therefore does not necessarily influence the economic activity of the region that includes the resource. Wennergren (7) points out that the estimated value of the resource is merely a monetary expression of the benefits extracted by users less their cost of participation.

The second measure of value that can be derived from the demand curve is known as the nondiscriminating monopolist's value. In this measure, the value of the resource is expressed as the maximum revenue a single owner of the resource

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The interested reader is directed to Barkley (1) for a review of the history of these techniques.

The price actually paid is the mean ons-te cost for all groups visiting the site.

could collect on a yearly basis. A rational monopolistic owner would seek to maximize the total revenue from the use of the resource, given that it was profitable to operate at all. Since he could not practically discriminate between users based on their willingness to pay, he would have to set one "ideal" price. If the monopolist were able to effectively discriminate between users it would be possible for him to capture a revenue equal to the entire consumer's surplus. At his ideal price, located at the point of unitary elasticity on the demand curve, the monopolist would receive the maximum revenue the resource could yield him.

The nondiscriminating monopolist's value is an appealing concept since the government could in many ways be thought of as a single owner of our public recreational resources. The value generated by this method indicates the maximum revenue obtainable if a user's fee system were implemented at the site.

Which of these two measures should be used in establishing the limiting case benefit of the proposed soil erosion control program? Generally, the use of the nondiscriminating monopolist's value is indicated when a particular alternative is being compared to other non compatible alternatives that may result in real cash returns. Such a situation could exist if a parcel of federally owned land was being considered for use as either a recreational area or a coal mining site. Clearly the sale of coal would generate direct cash revenues, whereas the recreational alternative would produce less tangible but no less real benefits. In this case the use of the nondiscriminating monopolist's value would result in more uniformly comparable benefits.

On the other hand, consumer's surplus benefits generally are used for singular public investment decisions. In such situations the improvement of society's welfare is the main goal and the total social benefit produced by the program should be taken into account. Consumer's surplus will do this. Since the proposed soil erosion control program is clearly most similar to this latter situation, consumer's surplus was the primary measure used in calculating the limiting case benefit. The smaller benefit yielded by the nondiscriminating monopolist's method was used only for comparative purposes.

Sampling Design and Model Variables

Since detailed data on recreationist expense and usage were nonexistent, it became necessary to survey the Lake Chicot user population. During the summer of 1980, via random onsite personal interviews, 96 groups were questioned. From this presample it was determined statistically that a total sample size of 385 parties would be required. To obtain the remaining 289, a mail survey of users was undertaken. Names of recreationists who had visited the lake from October, 1979, to September, 1980, were chosen randomly from State Park records. Of the 470 questionnaries mailed, 283, or 60.2 percent, were eventually returned in usable form[10].

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[10]A copy of the questionnaire/interview form can be found in Osborn (5) or obtained from the Department of Agricultural Economics. Room 222 Agriculture Building. University of Arkansas. Fayetteville 72701

If the completed questionnaire was not returned within four weeks of the original mailing. a follow-up postcard was sent. If after another four weeks no response was forthcoming a third and final correspondence containing a second questionnaire was sent.

To investigate the possibility that nonresponse bias affected the integrity of the sample, a random 10 percent of the nonresponding portion of the mail survey group was questioned by phone. It was determined statistically that the responses given by those not responding originally were not significantly different from those given by parties responding to the questionnaire.

In addition to information about recreationist expenses and usage, information was collected concerning other economically important factors that could affect the demand for recreation. The remainder of this section is devoted to a discussion of the independent variables used in the regression analysis and their hypothesized economic effects.

The determination of travel cost (X1) was limited to those expenses actually incurred by a party on their way to and from the lake. In the majority of cases the sole purpose of a party's trip was to recreate at Lake Chicot specifically. For some parties, however, the visit was merely a side stopoff on a much longer journey. In such situations, travel cost was calculated as only the expenses the party incurred to go out of their way to visit the lake. Obviously a major component of travel cost was gasoline expense. In addition, however, expenses included food and beverages, lodging, souvenirs, and entertainment. Food and beverage expenses were those above and beyond what the party would have consumed over the same time period had they elected to stay at home (6). Total travel cost was found by summing the above expenses. Economic theory would indicate that travel cost should affect length of visit in a positive manner.

Onsite cost (X2) was limited to those expenses groups incurred while actually recreating at the Lake. This included such items as food and beverage, camping fees, boat rental, boat operation, bait, camping equipment rental, camera supplies, minor equipment repair, onsite auto milage, souvenirs, entertainment, etc. In addition this study included in onsite cost any wages or income foregone by members of the recreating group (if a group was on a paid vacation their opportunity cost was simply zero). As before, food and beverage expenses were those above and beyond what the party would have incurred had they elected to remain at home (6). After summing all these expenses, the resulting total variable cost was divided by the length of visit to yield onsite cost per hour. This variable was used as the proxy for price in regard to number of hours per visit. It was expected that a negative effect would be shown.

Income (X3) was obtained through a question requesting that the respondent indicate to which of a number of income categories his family belonged. The 16 categories ranged from $0 to $43,000 and above. This approach was adopted in the hope of minimizing non response. For analysis, the midpoint of the chosen range was taken as the approximate family income. It was expected that income would have a positive effect on length of visit, or that the higher the income, the greater the amount of recreation demanded.

Current value of investment in recreational equipment (X5) was obtained by presenting each respondent with a comprehensive list of various equipment items. If the family did own one, they were asked to supply the year of purchase, the

original purchase price, and their appraisal of its current value. In addition they were asked to indicate the percentage of the item's total use time devoted to Lake Chicot. Purchase year and purchase price were used only to check the reasonability of the individual's appraisal of current value. When at all possible, the respondent's current value estimate was used. For each item of equipment, the current value was multiplied by its percentage of total use time at Lake Chicot to determine the actual investment in that item toward Lake Chicot recreation. Total investment expenditure toward Lake Chicot was obtained by summing all items owned by the family. Investment in recreational equipment can generally be considered as an indication of strong preferences for recreational activities and may, in many cases, substitute for onsite expenditures. Thus, amount of investment expenditure was hypothesized to have a positive effect on length of visit.

Number of visits per year (X6) was obtained by asking interviewed groups how many times in the previous 12 months they had visited the lake. As an independent variable, number of visits per year was hypothesized to have a negative effect on length of visit. One would expect that as more visits are taken, the duration of each particular visit would become shorter.

Number in party (X7) was acquired through the use of a direct question. In most cases the party was composed of a single family unit. It was hypothesized that the number in the party would be positive in its effect on length of visit.

The determination of age (X8) was also accomplished through a direction question. Age in this study represented that of the individual being interviewed. In most cases this was the male head of the household, the so-called leader of the group. The effect of age on length of visit and number of visits per year depends primarily on the age structure of the market population. Populations composed of large percentages of the middle-aged tend to exert a negative effect on recreation while those composed of large percentages of younger or older individuals tend to have a positive effect on quantity of recreation demanded.

Analysis of Empirical Models

Computer analysis of models by multiple least squares regression was accomplished through the use of the General Linear Models procedure of the Statistical Analysis System at the University of Arkansas. Models using both the linear and the curvilinear form of the dependent variable Y were tested[11]. Since the curvilinear form produced the best predictive results, further analysis will be concerned only with those models using the curvilinear form of the dependent variable. The general theoretical model can thus be written:

$$Z = f(X1, X2, X3, X5, X6, X7, X8)$$

Cross correlation coefficients for all independent variables were calculated and analyzed for possible problems such as multicolinearity. It was determined that no such problems existed.

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[11] The curvilinear form of the dependent variable Y (length of visit) is the natural logarithm of Y which shall be indicated as Z.

Subjecting the data collected for both basins of Lake Chicot to multiple least squares regression using the general theoretical model, the following empirical models were obtained:

Northern Basin
(1)

$Z = 3.34023844 + .01992230\ X1 - .18000183\ X2 - .00000146 X3 + .0000884\ X5 + .01108047\ X6 + .03047755\ X7 + .00273282 X8$

R-SQUARE = .386668   ADJUSTED R-SQUARE = .373775

F-VALUE = 29.99   X1, X2, & X5 significant at 10%

Southern Basin
(2)

$Z = .84735896 + .39097763\ X1 - .00684022\ X2 + .00000778\ X3 + .00046729\ X5 - .01522047\ X6 + .08261355\ X7 - .01630419 X8$

R-SQUARE = .493128   ADJUSTED R-SQUARE = .423557

F-VALUE = 7.09   X1 and X5 significant at 10%

WHERE:

Z = natural log of length of stay
$X1$ = travel cost; $X2$ = onsite cost
$X3$ = income; $X5$ = investment
$X6$ = visits per year; $X7$ = number in party
$X8$ = age

T-tests indicated that in the model for the northern basin, income, visits per year, number in party, and age were not significant predictor variables for length of visit. To refine the model, differing combinations of these non-significant variables were dropped from the model. Special attention was given to the movement of the adjusted r-square. This statistic should be used in addition to the regular r-square since it tends to compensate for the loss of predictor variables. An increase in the adjusted r-square signals a model with superior explanatory power with fewer independent variables. The resultant model was one in which income, visits per year, number in party, and age were dropped causing the adjusted r-square to improve. This model appears as:

Northern Basin
(3)

$Z = 3.57406434 + .01943378\ X1 - .18256554\ X2 + .0000972\ X5$

R-SQUARE = .386112   ADJUSTED R-SQUARE = .381025

F-VALUE = 75.89   X1, X2, & X5 significant at 10%

For the southern basin, t-tests indicated that onsite costs, income, visits per year, number in party, and age were not significant predictors of length of visit in the regression analysis.

All possible combinations of the above variables were dropped from the model, but in no instance did the price proxy, onsite costs, show even the slightest significance. The resultant best model was one in which X2, X3, X6, and X7 were dropped yielding:

Southern Basin
(4)
$$Z = 1.19307737 + .39428329\,X1 + .00047120\,X5 - .01546546\,X8$$
R-SQUARE = .462516   ADJUSTED R-SQUARE = .435624
F-VALUE = 17.21   X1, X5, and X8 significant at 10%

Since X2, onsite costs, was shown to be highly insignificant, price must have little effect on the quantity of recreation demanded on the southern basin at moderate price levels. Travel costs, investment expenditures, and age are better predictors in regard to length of stay on this basin.

To establish the northern basin demand equation for the average party, the mean values of X1 (travel cost) and X5 (investment expenditure) were inserted into equation (3) for the northern basin. By converting the curvilinear form of the dependent variable back to the linear form, the price quantity relationship became:

Northern Basin Demand Equation
(5)
$$Y = e^{**}(4.0810548 \text{ x } .18256554\,X2)$$
where ** indicates exponentiation

By allowing X2, onsite costs, to vary from the minimum northern basin onsite cost of \$0.09/hour to the maximum northern basin onsite cost of \$13.04/hour, the average party demand equation for the northern basin was established, as shown in Figure 4.

The demand equation for the southern basin was obtained by substituting its mean values for X1, X5, and X8 into equation 4. The resulting equation after converting Z to Y became:

Southern Basin Demand Equation
(6)
$$Y = 3.5939458$$

By plotting this equation from the minimum southern basin onsite cost of \$0.33/hour to the maximum southern basin onsite cost of \$11.01/hour, the

perfectly inelastic demand curve for the average southern basin party was established as shown in Figure 5. Since no recreation is demanded above $11.01/hour, the demand curve is essentially perfectly elastic at this price.
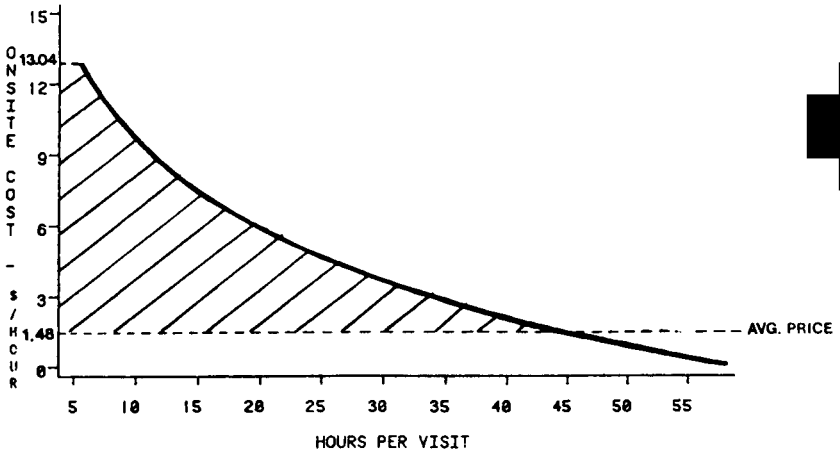

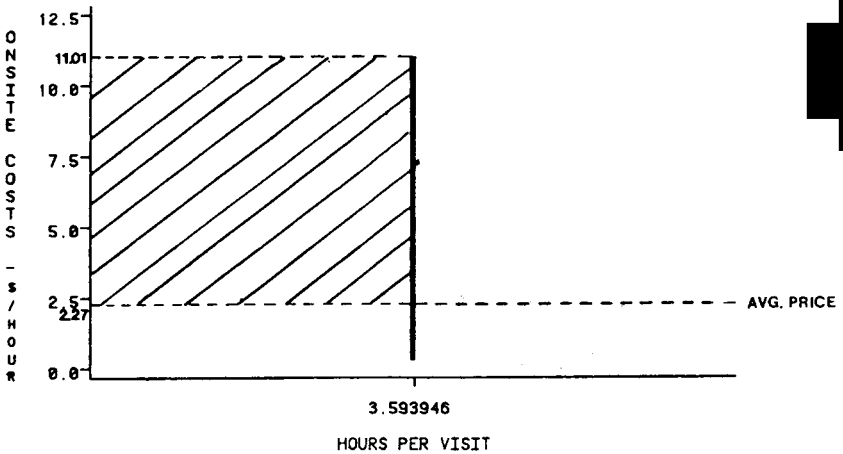Fig. 4. Recreational Demand Curve for the Northern Basin of Lake Chicot

Fig. 5. Recreational Demand Curve for the Southern Basin of Lake Chicot

Consumer's Surplus and Limiting Case Benefit

To determine the consumer's surplus value for the northern basin, equation #5 was integrated from the average northern basin price of $1.48/hour to the maximum northern basin price of $13.04/hour. This is geometrically represented in Figure 4 as the cross-hatched area. The result of this integration indicated that the consumer's surplus for an average party visit to the northern basin is $217.53.

In other words, the average party receives $217.53 worth of benefit above and beyond their costs of procurement for a visit to the northern basin. To obtain the total consumer's surplus value for the northern basin, it was necessary to multiply the number of visits per year to this basin by $217.53. According to information obtained from the Arkansas Department of Parks and Tourism, approximately 45,100 visits were made to the northern basin from October, 1979, to September, 1980. Thus the consumer's surplus value for the northern basin for these 12 months is $9,810,603.00.

Consumer's surplus value for the southern basin was found by taking the integral of equation #6 from the average onsite cost for this basin of $2.27/hour to the maximum basin onsite cost of $11.01/hour. The geometrical representation of this area is shown cross-hatched in Figure 5. The outcome of this integration indicated that the average party's consumer's surplus per visit equals $31.38. To approximate the total yearly consumer's surplus value for the southern basin, it was necessary to multiply the number of visits to this basin during the period by $31.38. From the sample taken in this study it was determined that 17 percent of the groups visiting the northern basin also visited the southern basin on a particular visit. Additionally, for all practical purposes, no one travels to the Lake with the purpose of recreating solely on the southern basin. Therefore, the number of visits to the southern basin for the period of October, 1979, to September, 1980, can be approximated as 17 percent of the number of visits to the northern basin over the same period, or 7,834 visits. Thus, the resulting yearly total consumer's surplus value for the southern basin is $245,826.84. From this information it was possible to estimate the limiting case benefit of the proposed soil erosion control program simply as the difference between the northern basin recreational value and the southern basin recreational value. The consumer's surplus limiting case benefit is equal to $9,564,776.16.[12]

SUMMARY ANALYSIS

Using the information developed in the preceding sections, it was possible to calculate a benefit-cost ratio (b/c) for the soil erosion control program that would at least maintain the present water quality of the northern basin of Lake Chicot. If the resulting b/c ratio, found by dividing the present value of benefits by the present value of costs, is greater than one the program is desirable from an economic viewpoint since it adds more to society's well-being than it takes away. Alternatively, if the b/c ratio is less than one, implementation of the program would be questionable since costs would be greater than benefits.

Present Value of Costs

In the cost estimation phase of this study it was shown that the least cost method to effect any reduction in soil erosion was through an average soil loss restriction.

[12]The nondiscriminating monopolist's value for the northern basin was $4,106,806.00 while this value for the southern basin was $245,826.84. This produced a nondiscriminating monopolist's limiting case benefit for the erosion control program of $3,856,979.20.

Due to a lack of expert consensus or actual physical investigation, it has been deemed reasonable for analytical purposes that soil loss from the surrounding watershed would have to be decreased by approximately 50 percent to maintain the present water quality of the northern basin of Lake Chicot. Thus, soil loss would have to be reduced from the 1979 actual loss of 4.2 TAY to approximately 2.0 TAY. As shown in Table 4 the 2.0 TAY average restriction would accomplish this in a least cost manner. In comparison to maximum returns, a restriction of this level would cost (in terms of subsidies or taxes) $4.16 per acre each year. Multiplying this by the number of acres of cropland in the watershed yields a total yearly program cost of $42,390.00 not including administrative costs. Assuming a project life of 50 years and a discount rate of 7⅜ percent, the present value of costs for such a program would equal $599,583.00.[13]

Present Value of Benefits

It is to be expected that, in the absence of a soil erosion control program, the recreational value of the northern basin would decline little in the very near future. Thus, for the first few years of any erosion control program, benefits would be small. As time passed, however, we would expect that program benefits would increase until they reached an upper bound equaling the limiting case benefit. From that point on, for the life of the program, each year's benefit would be equal to the limiting case benefit. It has been assumed that given present erosion rates in the absence of a soil erosion control program, it would take approximately 20 years for the water of the northern basin to become like that of the southern basin in terms of recreational usage. It was additionally assumed that during this period the decline would proceed at a constant rate. Therefore, starting with an initial year benefit of zero and using the consumer's surplus limiting case benefit derived earlier, it is clear that benefits in years 1 thru 20 would increase yearly by $478, 238.81. In year 20 and for the remaining years of the program, the full limiting case value of $9,564,776.20 would be realized.

Again assuming a discount rate of 7⅜ percent and employing the consumer's surplus limiting case benefit, the present value of benefits for the program would be $67,694,000.00. If one were to utilize the nondiscriminating monopolist's limiting case benefit while retaining the above assumptions, the present value of the program would equal $27,297,300.00.

Project Feasibility

Dividing the present value of benefits found using the consumer's surplus limiting case benefit by the present value of costs yields a b/c ratio for the 50-year project of 112. If one were to employ a 20-year planning horizon while retaining all other assumptions, the resulting b/c ratio would equal 81. The magnitude of these ratios clearly implies that initiation of such a program would be highly desirable from society's standpoint.

As was reasoned earlier, the consumer's surplus limiting case benefit is the appropriate measure of value to employ in regard to projects of the type being considered. Nevertheless, it may be of interest to observe the b/c ratios resulting from the use of the nondiscriminating monopolist's limiting case benefit. Dividing the present value of benefits found in this way by the present value of costs yields a b/c ratio for a 50-year program of 45. Employing a 20-year planning horizon produces a b/c ratio equaling 33. While these ratios are less than those produced using the consumer's surplus limiting case benefit, the project is still supported overwhelmingly.

In addition to the recreational benefits resulting from the erosion control program, other benefits may result. First, individuals owning homes near the lake would probably enjoy higher property values associated with living next to a clean versus silty body of water. Second, some individuals who never use the lake for recreation may nevertheless derive utility from the mere fact that the lake is being kept clean. For some at least, their option to use the lake at a future date is thus preserved. Lastly, other benefits that may result include maintaining the productive capacity of the soil over a longer period of time, reduced maintenance cost for drainage ditches, and multiplier effects to the local economy from increased farm incomes. While these are real benefits that could be credited to such a program, for the purposes of this study only recreational benefits were counted. Due to the nature of the lake, recreational benefits are by far the most significant, and their preservation is the primary goal of the proposed program.

Recommendations

The purpose of this study was to determine the most cost effective soil erosion control program to maintain the current recreational viability of the northern basin of Lake Chicot and, given this, through benefit-cost analysis to establish whether or not such a program could be economically justified. Studies of this type are essential if scarce public monies are to be used in an efficient manner. Results indicate conclusively that a project of this sort should be undertaken.

Initially top priority should be given to an intensive educational program designed to inform farmers that alternative production practices could not only reduce soil loss but also increase their net returns. Currently farmers in the north Lake Chicot watershed are neither maximizing net returns nor minimizing soil loss. It is assumed that the benefits of an educational program (up to $23/acre) would greatly exceed the costs incurred to administer such a program.

The single most important factor affecting soil loss, and net returns to the farmer, is wheat production. When wheat is grown as a double crop with soybeans, soil loss is reduced by 57 percent and net returns are increased by 97 percent. Converting all the continuous soybean production in the 1979 actual situation to wheat-soybean double cropping could account for most of the increase in returns and reduction in soil loss of the maximum returns situation compared to the actual 1979 situation.

The decrease in soil loss above that associated with maximum net returns could

be accomplished most economically through an average soil loss restriction. A 2.0-ton per acre per year average, 1.2-ton per acre per year less than the maximum returns situation, would result in a 50 percent decrease in soil loss compared to 1979. Operationally this restriction could take form as an erosion reduction subsidy, by paying farmers $3.47 for each ton of soil loss reduced from the loss associated with maximum returns ($4.16 decrease in net returns divided by a 1.2-ton per acre per year reduction in soil loss). Alternatively, implementation of this restriction could be accomplished through a soil loss tax whereby farmers would be charged $3.47 for each ton of soil lost per year.

An average soil loss restriction would give the farmer flexibility in deciding for himself how best to decrease his soil loss. The average soil loss restriction theoretically achieves a given total soil loss reduction at the least cost. However, this is true only if administrative costs, which were not estimated in this study, are ignored. Unfortunately, these costs may be prohibitive, given the nature of the problem. Other programs such as the cover crop only alternative may be more easily administered, resulting in significant reductions in soil loss (2.32 TAY average) and having little impact on farm income.

The Soil Conservation Service, through the Conservation District, can provide the expertise needed to develop individual control plans and to determine the farmer's soil loss before and after initiation of controls. Each farmer is encouraged to contact the Soil Conservation Service and his county Extension agent to develop effective crop rotations and soil conservation plans.

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