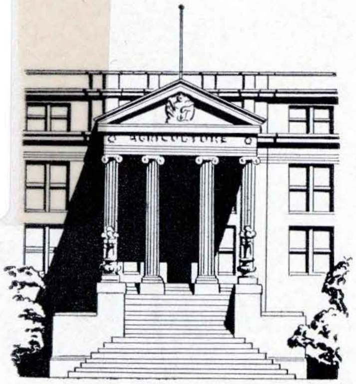

Soil Erosion Control In Western Iowa: Progress and Problems

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SUMMARY

The study on which this analysis is based was concerned with the socio-economic factors that prevented erosion control in western Iowa from coinciding with goals of erosion-control programs. Information was obtained by personal interview from 138 farm operators and 49 nonoperating owners of farms in the area in 1957 in a continuing investigation of the obstacles preventing adoption of erosion-control practices and of possible remedies for these obstacles. The same sample of farms had been included in two previous studies in 1949 and 1952. Data from these three studies were used to analyze the effects of changes in obstacles to erosion control on changes in soil loss.

The average estimated annual soil loss for the sample decreased from 21.1 to 14.1 tons per acre from 1949-57. In an effort to determine why the 5-ton-per-acre goal of public programs in the area had not been attained in 1957, multiple variable linear regression was used to analyze the relationships between obstacles, farm characteristics and soil losses. The statistically significant obstacles preventing the reduction of soil losses by farm operators were (1) operators' need for immediate income, (2) their failure to see the need for recommended practices (custom and inertia) and (3) field and road layout of the farms. Characteristics which explained a significant amount of variation in the estimated soil loss were (1) topography of the farm, (2) soil conservation district participation, (3) the operator's ability to borrow funds for erosion-control practices, (4) days of off-farm work and (5) recognition of the seriousness of the erosion-control problem by farm operators. While not statistically significant, the most important obstacles for nonoperating landowners were (1) need for immediate income and (2) insufficient roughage-consuming livestock on tenant-operated farms.

Characteristics mentioned by nonoperating landowners which explained a significant amount of variation in estimated soil loss on tenant-operated farms were (1) topography, (2) expectation of owning the farm in 1 year (from the date of the interview), (3) need to borrow funds to establish erosion-control practices, (4) additional acres of land owned and (5) tenant's need for immediate income. Farms on which five of the most important operators' obstacles had persisted since 1949 had average soil losses above the sample mean; those without these obstacles had average soil losses below the sample mean. Nevertheless, a significant amount of variation in changes in estimated soil loss between 1949 and 1957 was not explained by changes in obstacles found to be important in 1949.

Several remedial measures were suggested. These included (1) a refined and extended method of farm planning with follow-up planning using costs and returns information obtained through further research, (2) additional education about the seriousness of the erosion problem, (3) education of tenants and nonoperating landowners about crop- and livestock-share leases, (4) educational programs about compensation clauses in leases, (5) greater use of long-term loans to cover the initial costs of erosion-control practices, (6) additional effort to inform farm people of nonfarm employment opportunities and (7) revision of real estate tax rates based on long-term land productivity under erosion-control practices.

Further research is needed to (1) estimate future land use in the area, as a guide in determining the amount of erosion control needed, (2) analyze the consequences of related federal programs on resource use, (3) improve terrace designs, (4) study factors which determine soil conservation district participation, (5) determine how farm operators and nonoperating landowners form their opinions about erosion-control practices, (6) analyze methods of controlling land use through rural zoning with compensation provisions financed by public grants-in-aid, (7) determine land use requirements as a basis for agricultural aid from the federal government, (8) investigate direct controls on the upper limit of land deterioration and (9) establish possible bases for incentive payments in accordance with the costs of practices above farmers' levels of profitable erosion-control investments.

Soil Erosion Control In Western Iowa: Progress and Problems[1]

BY MELVIN G. BLASE AND JOHN F. TIMMONS[2]

Evidence of the problem of controlling soil erosion is easily discernible in western Iowa. The problem persists in spite of considerable expenditures by private individuals and public agencies to reduce soil erosion. Research, education and incentive payment programs undertaken by public agencies have not induced farmers in the area to adopt enough erosion-control practices to reduce erosion to the level set by the programs. This report presents methods of research and findings that show (1) extent of soil erosion in process, (2) factors affecting rate and extent of soil erosion and (3) indications of how erosion control may be made more effective.

THE PROBLEM OF SOIL EROSION CONTROL

The soil-erosion-control problem has many facets.[3] One is the physical facet of the problem which can be examined from the aspects of space and time. The interspatial aspect deals with the physical movement of topsoil from one area to another. It occurs through gullying and sheet erosion in the upper reaches and siltation in the lower areas in a watershed. The intertemporal aspect concerns the rate of topsoil movement in relation to time. Enough soil may be removed through erosion to impair plant production on most sloping lands.

Directly related to the physical facet of the erosion problem are the economic considerations. The physical phase of the problem is important in that soil loss has economic consequences for the operator of the farm, for parties downstream who may be damaged by siltation and flooding and for society, which has a longer planning horizon than does the individual operator.

A growing population will probably cause our future food and fiber needs to be greater than they are at present. Consequently, additional agricultural output must be forthcoming either from more resources being employed or from an increase in technology, which results in more efficient use of given resources, or a combination of the two. Continuing soil erosion may increase costs of agricultural products to consumers and endanger national security in international emergencies. In any event, the rate and magnitude of soil loss are important considerations to farmers, consumers and the nation.

Primarily in the long planning period, 25 years or longer, society's interest outweighs that of the individual owner and operator. The economic phase of the soil-erosion-control problem can be summarized as falling within the following classifications: intraspatial, interspatial, intratemporal and intertemporal disassociations of costs from benefits (43, pp. 1170-1184).

In addition to the physical and economic phases of the erosion-control problem, there are institutional considerations which should be recognized. In this analysis, institutions are defined as social controls over individual actions. As such they either facilitate or hinder soil erosion control. Although frequently considered rigid and inflexible, institutions are man-made and, consequently, can be adjusted as society desires.

One of the institutions significantly affecting erosion control is ownership of land in fee simple. Through this institution, society has conveyed to the individual owner the right to use resources in an almost unlimited fashion. Other institutions affecting soil erosion control include predominate types of field boundaries resulting from the rectangular survey, tax assessments on landed property and customary types of tenancy. A thorough analysis of all the institutional factors affecting erosion control would be a task in itself; thus, only the institutional factors which influence the adoption of erosion-control practices were considered here.

An examination of the soil-erosion-control problem does not reveal mutually exclusive physical, economic and institutional parts. On the contrary, they are closely intertwined. Division of these parts would be desirable from an analytical standpoint. Since failure to adopt erosion-control practices stems from a com-

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[3] The term "soil erosion control" rather than "soil conservation" has been used in this analysis. The precise definition for the former can be found in Appendix A.

bination of physical, economic and institutional factors, however, consideration must be given to these three aspects of the problem.

Area of Study

The Ida-Monona soil association area of western Iowa was selected for the analysis. The primary reason for this choice was that previous research in the area by Frey (14) and Held (20) had revealed serious erosion losses, as well as a number of obstacles preventing the adoption of soil-erosion-control practices. Data obtained in these earlier studies provided foundations for studying the processes through which soil erosion takes place and may be controlled.

RELATION OF THIS STUDY TO PREVIOUS RESEARCH

The area was originally selected for study in 1949 because of the apparent seriousness of the erosion problem. The steep slopes, large acreages in intertilled crops, distribution of rainfall and insufficient erosion-control practices have resulted in extensive sheet and gully erosion. Erosion presents a problem not only on the upland slopes, but also on adjoining bottomlands through flooding and silting in drainage channels. Severe erosion has developed, despite the fact that the area has been farmed less than 90 years. Erosion has decreased farming efficiency because of more difficult access to fields, increased wasteland and increased costs of providing satisfactory public roads (14, p. 951) (20, p. 298).

Frey estimated the average annual soil loss in the Ida-Monona area as 21.1 tons per acre in 1949. Eighty-nine percent of the farmers had not reduced their soil losses to the annual rate of 5 tons per acre, the goal used by public programs in the area. Also, 79 percent of the farmers had erosion-control objectives that would allow soil losses of more than 5 tons per acre. If these farmers had adopted the erosion-control practices which they believed to be necessary, soil losses would have averaged 16.4 tons per acre per year.

When presented with farm plans that would hold soil losses to an average of 5 tons per acre, farmers had several objections. Frey found four major obstacles which appeared to retard farmers in reaching the program's erosion-control objective. These four obstacles, which when tested indicated a significant difference in the rate of soil loss, were (1) change in farm enterprises (primarily to more livestock) on 40 percent of the farms, (2) rental arrangements and the landlord's cooperation on 34 percent of the farms, (3) mortgage indebtedness and the annual fixed cash outlays for operating and living expenses on 30 percent of the farms and (4) short expectancy of tenure on 19 percent of the farms. Combinations of two or more obstacles were discovered on some of the farms. The change in farm enterprises, the tenure situation and the number of acres operated per farm entered into most of these combinations (14, p. 945).

The second study in this series was undertaken by R. Burnell Held (19). In 1952, he reinterviewed the operators of the same sample of farms that Frey had used in 1949. Soil losses in the Ida-Monona soil area were estimated to have decreased slightly, 1.6 tons per acre, between 1949 and 1952. Still, the average soil loss for farms in the sample was 19.5 tons per acre. As a group, the operators had not succeeded in reaching their own erosion-control goals of 16.4 tons of average soil loss per acre which they had mentioned in 1949. Nor did the operators set goals in 1952 which were more ambitious. The practices which they named as needed on their farms would have resulted in soil loss rates averaging 16.7 tons per acre if they had been used.

While the average soil loss indicated little change in the erosion situation, there were actually noteworthy increases and decreases in soil loss rates on individual farms. Thirty-six farms with high rates of loss in 1949 had reduced these losses by 5 tons or more in 1952. Others showed increases in the rate of loss of similar magnitude.

In 1952, Held reviewed the major causes for failure to reduce soil losses and identified these causes as (1) uncertainty of tenure, (2) lack of adequate finances, (3) reluctance to assume risk and (4) lack of confidence in recommended practices. The major success elements causing a reduction in soil losses appeared to be (1) increased appreciation of the seriousness of soil losses, (2) increased security of tenure and (3) increased appreciation that a shift to more grass on the steeper slopes and an increase in numbers of forage-consuming livestock were conducive both to erosion control and profitability of farming over the long pull (20, p. 296).[4]

SOIL CHARACTERISTICS

The Ida-Monona-Hamburg soil association is a long, hilly belt of land bordered by the Galva-Primghar-Sac soil association on the north, the Marshall soil association on the east, the state of Missouri on the south and the Missouri River floodplain on the west. Approximately 5 percent of the state is included in the area.

Ida and Monona soils constitute more than half the land in the association. Both soils were formed from calcareous loess on hilly topography. The thickness of the loess decreases from a maximum of about 120 feet near the river valley, which is thought to be its source, to a thin loessial mantle in north-central Missouri. Most of the parent material is not 120 feet thick in the Ida-Monona soil association, but there are many road cuts 15 to 20 feet deep in the loessial deposition.

These soils are susceptible to erosion. Measures which reduce water runoff—such as level terracing, contour surface planting and contour listing—aid in reducing both soil erosion and the drouth hazard. Without these practices, gullying develops rapidly and severely. Partially as a result of erosion, fertility problems become more acute in this area than in most others in Iowa (37, pp. 58-62).

[4] Other studies indirectly related to research on obstacles to soil erosion control have been untertaken in this area. These include a study by Toussaint on optimum rental arrangements for conservation systems of farming (46); an inquiry by Baumann, *et al.*, into costs and returns on soil-conserving systems of farming on 160-acre tracts in western Iowa (3); a study of the cost and returns of capital requirements for soil-conserving farming on rented farms in western Iowa by Jensen, *et al.* (26); an inquiry by Dean, *et al.*, into the optimum use of farm resources on two different size units and conservation systems in the Ida-Monona soil association area (11); an analysis by Ball, *et al.*, of the economics of soil conservation practices individually and as part of whole farm plans (2); and an investigation into progress and problems in the Iowa Soil Conservation District Program by Fischer and Timmons (13).

The extent of the erosion problem has been further shown in the National Survey of Soil and Water Conservation Needs recently completed in Iowa by the United States Department of Agriculture. This survey indicated that the modal acreage of Monona silt loam was found on slopes between 5 and 13 percent within erosion class II in the Ida-Monona soil association area.[5] In comparison, the classes with the largest acreages of Ida silt loam fall within erosion class III, but on slopes from 9 to 17 percent.[6] In view of these soil characteristics, erosion-control programs have a real challenge in this area. Although the number of basic farm plans prepared by the Soil Conservation Service on farms in counties with Ida and Monona soils has been increasing, only 30 percent of the farms had basic plans in 1959.[7] Although more than $1 million was spent in the area in 1958 by the federal government for Agricultural Conservation Program cost-sharing payments, these payments were made on less than 20 percent of the farms.[8] In addition to these payments, land had been placed in the conservation reserve during 1956-59 on 5 percent of the farms in the area. Consequently, present programs have not reached all farms in the area.

THE AGRICULTURAL ECONOMY IN THE IDA-MONONA SOIL ASSOCIATION AREA

The agricultural economy of this area is predominantly livestock feeding. Close proximity to central livestock markets in Omaha, Nebraska, and Sioux City, Iowa, has been an important factor in determining the type of farming in the area. Not only do these markets represent a source of supply of feeder cattle from western ranges, but also they represent an outlet for fat cattle and hogs. This type of an agricultural economy requires intensive use of land for the production of intertilled crops. This, in turn, leads to high levels of soil erosion.

The high proportion of land in cultivation indicates that the use of land for forage production is not highly competitive in the area. In addition to the close proximity to markets for grain-finished livestock, there is a correspondingly poor market for milk and dairy products. Furthermore, corn represents the highest profit crop for most farms in the area (26, p. 176). As a consequence of these factors, there is a higher percentage of land in intertilled crops than in other soil areas in Iowa with similar topography.

A smaller percentage of land in western Iowa is owned by operators than in the rest of the state (table 1). Since tenants usually have shorter planning horizons than do owner-operators, the relatively low proportion of owner-operated farms may be hypothesized as being an important factor contributing to the soil erosion problem. Also the data in table 1 show that farms in western Iowa had larger acreages, on the average, than those in the entire state. Since large farms tend to make more extensive use of land than small ones, the tendency toward large farms may help to relieve the erosion problem. The advantage of the relatively large size of farms in western Iowa is partially offset, however, by the amount of wasteland resulting from gullying in the Ida-Monona area.

TABLE 1. LAND TENURE AND AVERAGE SIZE OF FARMS IN WESTERN IOWA[a] AS REPORTED BY THE IOWA DEPARTMENT OF AGRICULTURE IN THE 1957 AND 1958 ASSESSORS' ANNUAL FARM CENSUS.

Crop reporting districts	Acres owned by operator (percent) 1957	1958	Average size of farms (acres) 1957	1958
Northwest	38.0	37.6	196	198
West Central	43.2	43.6	198	200
Southwest	49.6	49.6	199	201
State	50.2	50.3	184	185

[a] Districts covering western Iowa and the state totals were selected from all crop reporting districts in the state (23).

Objectives of the Study

This inquiry dealt with the extent of soil losses and the reasons why the present level of erosion exceeds the goal of public programs. The specific objectives of this inquiry were (1) to determine whether farmers had moved their soil-erosion-control goals toward the public goal between 1952 and 1957; (2) to determine erosion-control accomplishments by farmers in moving toward their own and the public goal; (3) to determine the changes in obstacle situations, the influences responsible for the changes and the effect of the changes in obstacle situations on the rate of soil loss; (4) to re-examine present and proposed measures for overcoming obstacles to erosion control and propose changes in such efforts or new efforts to make the programs more effective in achieving their objective of erosion control.

Procedure Used in the Analysis

The analysis used was normative in the sense that the research was focused on factors responsible for the difference between the problematic situation of erosion losses and the public norm of soil erosion control. This norm has been accepted for the analysis because of its use by public agencies charged with responsibility for reducing soil erosion. Although the norm was measured in physical terms and might have been questioned with regard to economic desirability, it was not the objective of this analysis to pursue such an investigation. Rather, this inquiry was designed to identify failure elements responsible for soil losses above this assumed goal and to find means to remedy these elements and attain the desired goal.

METHODOLOGICAL FRAMEWORK

Limiting the analysis to one soil area and to deviations of the problematic situation from the assumed norm was consistent with the methodological framework used. Achievement of the public goal is not an end in itself, but contributes to some higher order end-in-view leading to more ultimate ends of the society. Consequently, delimitation of the problem resulted in a manageable size analysis of one small segment within the means-ends continuum.

[5] Erosion classes are defined as follows: class I–6 to 7 inches or more of topsoil remaining; erosion class II–3 to 6 inches of topsoil remaining; erosion class III–less than 3 inches of topsoil remaining; erosion class IV–gullying restricts cultivation.

[6] Tyler, Lloyd, Ames, Iowa. Data from the national inventory of soil conservation needs. (Private communication.) 1960.

[7] Thoreson, Arthur, Des Moines, Iowa. Data from Soil Conservation Service records. (Private communication.) 1960.

[8] Sturgeon, Leo, Des Moines, Iowa. Data from Agricultural Stabilization and Conservation Committee records. (Private communication.) 1960.

Diagnosis of the problem required identifying the factors responsible for the problem and those factors which prevented it from being greater. Identification of obstacles, the failure elements, was made by analyzing (1) the reactions of representative farm operators and nonoperating landowners to sets of practices which would bring soil losses to the 5-ton level and (2) relating obstacles to erosion losses. The land use and other characteristics found on the sample farms were considered in diagnosing success and failure elements responsible for the present level of erosion-control-practice adoption.

The method of developing remedial measures was based upon the identification and appraisal of success elements associated with erosion control found on some of the farms. Also, other potential remedies were considered in light of the observed obstacles.

APPLICATION OF METHODOLOGY TO DYNAMIC PROBLEMS

This methodological approach to problem analysis is primarily applicable in static situations, but it can be used in the modified form of comparative statics to investigate problems which persist over time. To examine changes in the problem itself and the relative effectiveness of remedial measures over time, the investigation is repeated at different points in time, and the results are compared. This provides evidence to support or reject conclusions reached in diagnosing the problem and in developing remedial measures.

In this inquiry, the diagnostic and remedial phases were not limited to a static setting. Rather, they were applied to changes in obstacles that prevented the adoption of soil-erosion-control practices over time. By repeating the diagnostic and remedial phases of the methodology on a relatively unchanged problematic situation, it was possible to consider the dynamics of the problem through a comparative statics analysis.

FORMULATION OF HYPOTHESES THAT DIRECTED THE INQUIRY

The hypotheses which directed this analysis were:

Problem delimiting

1. If the soil erosion losses on farms in western Iowa are above the permissible rate of 5 tons of soil loss per acre per year, then certain obstacle situations exist that prevent this achievement.

2. If the present rate of soil loss exceeds the permissible rate of loss of the programs, as past inquiries have indicated was the case, then the rate of change in the obstacle situations has been less rapid than is sought in the programs.

Diagnostic hypotheses

1. If the soil loss exceeds 5 tons per acre, then the following obstacles are responsible: (a) insufficient roughage-consuming livestock, (b) the rental arrangement and the lack of landlord's cooperation, (c) the small size of farm, (d) the need for immediate income, (e) the price change expected, (f) the lack of adequate machinery and power, (g) the field and road layout, (h) a short expectancy of tenure, (i) risk and uncertainty, (j) the lack of adequate buildings, (k) custom and inertia, (l) the lack of an adequate labor supply, (m) the lack of cooperation of neighboring farmers, (n) the ability to shift the erosion losses, (o) the amount or kind of recommended practices, (p) failure to see the need for recommended practices, and (q) the lack of availability of credit.

2. If society's goal of 5 tons annual soil loss has not been gained, then certain socio-economic factors are responsible for preventing attainment of this norm.

3. If any of the observed obstacles are significantly different from those discovered by previous inquiries, then the rate of soil loss will have increased or decreased significantly depending upon the change in the obstacles.

4. If present measures of action agencies have been successful, the rate of change in soil losses will be significant.

Remedial hypotheses

1. If there are obstacles which have prevented the reduction of erosion losses to 5 tons per acre per year or less, then there are success elements on farms where erosion losses have been reduced which can be adapted to other farms.

2. If there are obstacles which have prevented the reduction of erosion losses to 5 tons per acre per year or less, then there are potential remedial measures dormant in the problematic situation which can be developed to overcome these obstacles.

ANALYSIS OF DATA

Analysis of data obtained from farm operators and nonoperating landowners resulted in acceptance or rejection of each of the delimiting, diagnostic and remedial hypotheses. Testing of the delimiting hypotheses required analysis of the data to determine the gap between program goals of erosion control and the problematic situation. If such a gap existed, as hypothesized, the delimiting hypotheses were tested further by tabulation of farm operators' and nonoperating landowners' responses of factors responsible for the erosion problem.

In the case of diagnostic hypotheses, statistical tests – primarily multiple variable regression – were employed to determine the likelihood of observed obstacles having as large an effect on soil losses as they appeared to have had in 1957. These tests were used to determine the relationships between selected farm characteristics and erosion losses. Finally, the relationships between farm characteristics and observed obstacles were analyzed. Using these procedures, diagnostic hypotheses were tested not only with data collected in 1957 but also with information obtained in 1949 and 1952. Consequently, the dynamic and static relationships between obstacles and erosion losses were investigated.

The problems involved in testing remedial hypotheses in the social sciences using controlled experiments, make it difficult to obtain statistical data for accepting or rejecting these hypotheses. As a result, analysis of those measures which might aid farm operators and nonoperating landowners in overcoming obstacles to erosion control was based primarily on inferences from relationships between success or failure elements and consequent erosion losses. This phase of the analysis was facilitated by the availability of data from 1949, 1952 and 1957.

SOURCES OF DATA AND SOIL LOSS CHANGES

To test the hypotheses, it was necessary to obtain certain information from farm operators and non-operating landowners. Information was needed to determine the extent of soil erosion, factors responsible for the problem, factors responsible for holding erosion losses within present limits and remedial measures for controlling erosion.

Method of Obtaining Data

The sample survey method of obtaining data was used. Farm operators and the owners of tenant-operated farms in the Ida-Monona soil association area were interviewed in 1957 to obtain most of the necessary data.

SURVEY DESIGN

The objectives of the study included not only an investigation of factors responsible for the failure of farmers to accomplish society's goal of soil erosion control, but also an analysis of changes in these factors over time. The latter objective necessitated use of the same sample used by Frey (14) and Held (19) in the earlier studies in this series.

Frey described the original procedure for drawing the sample as follows:

"In designing a representative sample of the area for the purposes of investigation, it was estimated that there would be three farms in each of the 1,602 sections of land. Thus a total of 4,803 farms was expected in the population under consideration. However, judging from the resources available, it was anticipated that observations could be made on only 140 or 150 of these farms. Therefore, 48 sections of land were selected at random to make up the area sample. The 48 sections were expected to contain 144 farms.

"In drawing the sample, 24 strata were created within the area, with each stratum containing either 66 or 67 sections of land. By drawing two sections at random within each of these 24 strata, the 48 sections of land in the sample were obtained. To make use of soils data already available, only those sections of land which had been partially mapped by a recent soil survey were permitted to come into the sample. The mapping in these sections was confined to 160-acre tracts of land included in another random sample of the entire state. Figure 1 shows the approximate location of the 48 sampling units obtained by this procedure.

"Each of the 48 sampling units in the Ida-Monona Soil Association Area was visited to determine the number of farms[9]

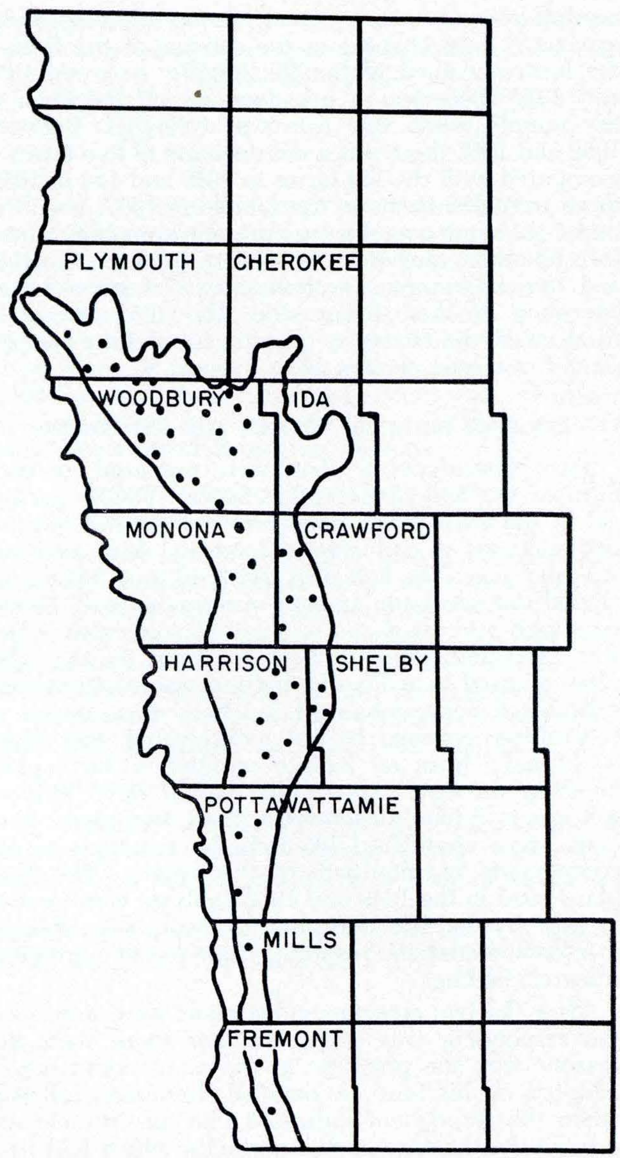

Fig. 1. Western Iowa showing the approximate location of the Ida-Monona soil association and the survey units in a sample of farms, 1957.

having a headquarters[10] within the boundaries of the sampling units and to delineate the boundaries of these farms on maps. The location of the farm headquarters served as an arbitrary guide in deciding whether or not a farm should be included in the study. The 48 sections actually contained 145 farm headquarters. Observations were made on all but 1 of the 145 farms." (74, pp. 952-953)

Since 1949, consolidation and division of farms resulted in a change in the number of farms in the sample. The criteria adopted for deciding whether a farm should remain in the sample was the headquarters' rule. That is, if the major managerial decisions in operating the farm were made from the same

[9] A farm, for purposes of this investigation, was all of the contiguous land and separate tracts of land on which some agricultural operations were performed by one person, either by his own labor alone or with the assistance of his household, or hired emp'oyees in 1949. Any tract of land less than 5 acres was not considered a farm. Only separate noncontiguous tracts of land which were operated from a designated headquarters in 1949 were considered as a part of a farm, although the operators were interviewed in 1950. Outlying noncontiguous tracts of land which were owned but not operated from a designated headquarters were not considered as a part of a farm. Outlying noncontiguous tracts of land on which a minor part of the field operations were performed as a basis for labor exchange were not considered as part of a farm, nor were outlying noncontiguous tracts which were operated under a partnership or cooperative arrangement from two separate headquarters.

[10] The farm headquarters for purposes of this investigation, was a dwelling on the farm and the building used for housing the major part of the livestock and machinery. If the dwelling was outside the boundaries of a section of land, but the buildings used for housing the major part of the livestock and machinery were within the section boundaries, the buildings for housing the major part of the livestock and machinery were considered as headquarters. If the buildings for housing the major portion of the livestock and machinery were outside the boundaries of a section of land, but the dwelling was located within the section boundaries, the dwelling was not considered as a headquarters.

headquarters as in the original sample—although there may have been changes in the acreage of the farm—the farm remained within the sample. Between 1950 and 1952 there was a net decrease of one farm in the sample when this rule was followed. Between 1952 and 1957 there was a net decrease of five farms.[11] Compared with the 144 farms in 1949 and 143 in 1952, there were 138 farms in the sample in 1957. On 77 of these, the same operator was present as in 1949. Fourteen operators moved to their farms between the 1949 and 1952 interviews. The remaining 47 farmers began operation of their farms since the 1952 interview. Analysis of the effects of changes in operators is presented in a later section of this report.[12]

EVIDENCE OBTAINED TO TEST THE HYPOTHESES

Two erosion-control plans were prepared for each farm by the Soil Conservation Service (SCS) personnel in the area. These plans represented two alternative methods of reducing soil erosion to 5 tons per acre per year. The first plan, referred to as Plan I, included the maximum amount of terracing and, correspondingly, the maximum amount of row crops which was consistent with the 5-ton-loss limit. In the other plan, referred to as Plan II, high-forage rotations were substituted for mechanical practices as a means of controlling erosion. It was conceivable that there could have been an infinite number of farm plans between the two plans which would have reduced soil loss to 5 tons. Reactions to these two plans, however, were considered likely to be reactions to the components of intermediate type plans. The farm plans used in the 1949 and 1952 analyses were revised in 1957 by the SCS personnel to incorporate changes in recommendations resulting from recent agronomic research findings.

After the two erosion-control plans were described, the respondent was asked whether there were any reasons why the practices in the plans could not be adopted on his farm. A detailed discussion followed when the respondent indicated that an obstacle was present. In the case of five obstacles which had been determined important in the earlier analyses, additional detailed questions were asked concerning reasons and remedies for the obstacles. Also, data concerning characteristics of the farm were obtained.

Schedules used in recording respondents' answers to the questions were basically the same as schedules used in the two earlier studies. Modifications were included to satisfy the additional objectives of this study without impairing the comparability of data obtained in the three studies.

[11] There were three situations where two farms within the sample were consolidated between 1952 and 1957. There were four farms which were no longer operated from their original headquarters and, therefore, were dropped from the sample. During this same time period, one farm was divided into two units. In addition, data were obtained from one farm operator who was not available in 1952. This resulted in a net decrease of five farms in the sample from 1952 to 1957.

[12] An effort was made to determine whether the previous interviews had injected a bias into the sample. The operators were asked whether they remembered the past interviews. The 68 who replied affirmatively were asked whether they had changed their farming operation as a result of those discussions. Sixteen said that they had made some changes in their farming system. The average soil loss on their farms was estimated to be 10.9 tons per acre. The soil loss on these farms declined 6.7 tons, on the average, between 1949 and 1957, compared with the average 7-ton decrease for the entire sample. Consequently, the previous interviews were considered not to have substantially affected the sample.

CODING AND TABULATION OF THE DATA

After schedules had been obtained from all 138 farm operators and owners of the 49 tenant-operated farms, the information was coded and placed on IBM cards. In most cases, the coding represented a mere transfer of information from the schedules; however, it was necessary to process some data before coding it. The most important of these processes was the conversion of land use, topography, crop management and erosion-control practice data into a soil loss estimate for each farm through use of the Browning Factors.[13] This dependent variable was used to indicate the extent of soil-erosion-control accomplishment.

SOIL LOSS ESTIMATES

CHANGES IN THE BROWNING FACTORS

As a result of agronomic research at Iowa State University and other Midwest experiment stations, the Browning Factors were revised in 1956 (24, pp. 1-5). To compare the soil loss estimates with those for 1949 and 1952 and it was necessary to recalculate the earlier estimates of soil losses using the revised Browning Factors.

The Browning Factors were changed considerably between 1952 and 1957.[14] Although the factors applied for management remained unchanged, there were extensive changes in the factors for special practices. In general, the effect of the changes in weights for these practices was to give less credit than was given in 1949 and 1952 for mechanical practices on steep slopes. It should be noted, however, that terracing was not recommended on slopes over 12 percent in 1949 and 1952. In 1957, rotations with a high percentage of meadow were given less credit than in 1949 and 1952. In most cases, the topography figures used in 1957 were lower than those used previously. Also, the constant term of 10 for converting the erosion index into tons per acre per year used prior to 1956 was reduced to 8.

Topography factors were used which represented a combination of Browning Factors for soil type, percent of slope, degree of erosion and an assumed 200-

[13] Soil loss can be calculated using the system of factors devised by Dr. George Browning which take into account and weight various physical factors that affect erosion. These are soil type, crop management, vegetative cover (as expressed in terms of rotations), use or nonuse of contouring, terracing, strip cropping or listing, degree of slope, length of slope, extent of previous erosion and a constant term. The weight given each factor is based on experimental data for the particular condition found. The product of the factors represents the estimate of the amount of soil lost from 1 acre in 1 year with normal weather. For example, in determining the annual erosion loss for 1 acre of land, the factors are assigned a value in the following manner:

Factor	*Value*
Ida soil type	1.5
10 percent slope	1.1
200-foot length of slope	1.7
corn, oats, meadow rotation	0.9
little or no manure or fertilizer applied	1.3
0 to 25 percent of surface soil removed	0.8
contour cultivation, surface planted	0.6
constant term to transform the index to an estimate of tons of soil loss	8.0

Substituting these values into the formula: (1.5) (1.1) (1.7) (0.9) (1.3) (0.8) (0.6) (8.0)=12.6 annual soil loss in tons per acre. If terracing with a value of 0.1 were substituted for contour surface planting, which has a value of 0.6, soil loss would be reduced from 12.6 to 2.1 tons per acre per year. For a detailed explanation of these factors, see "Browning's Factors" (24).

[14] See Appendix B for the Browning Factors that were used.

TABLE 2. SOIL LOSS ESTIMATES IN TONS PER ACRE BASED ON THE BROWNING FACTORS USED IN 1949-52 AND REVISED BROWNING FACTORS FOR A SAMPLE OF FARMS IN WESTERN IOWA IN 1957.

Year	Annual soil loss (mean, tons per acre) 1949-52 Browning Factors	Revised Browning Factors	Farmers' goals of soil loss (mean, tons per acre) 1949-52 Browning Factors	Revised Browning Factors
1949	21.6	21.1	15.6	16.4
1952	19.7	19.5	15.9	16.7

foot length of slope within each SCS class of land.[15] This procedure was followed in 1957 to reduce the calculations and to preserve continuity of method. As a result, comparison of soil loss estimates for all 3 years was possible.

The same research findings which changed the Browning Factors were responsible for changes in recommendations by SCS technicians in the Ida-Monona soil association area. Since 1956, the tendency has been to recommend more terracing on steeper slopes, particularly those above 12 percent, and to place less reliance on high-forage rotations.

REVISED SOIL LOSS ESTIMATES FOR 1949 AND 1952

Revision of the 1949 and 1952 soil loss estimates using the revised Browning Factors resulted in substantial changes in these estimates. As shown in table 2, the soil loss estimates were 0.5 and 0.2 ton per acre lower in 1949 and 1952, respectively. Revision of the estimates of farmers' goals of erosion control resulted in lower goals (higher soil losses) than in the earlier calculations. In 1949, the mean soil loss estimate for farmers' goals in the sample increased from 15.6 tons per acre per year to 16.4. Likewise in 1952 the soil loss estimate of farmers' goals increased from 15.9 to 16.7 tons per acre. The decrease in the estimate of soil losses in 1949 and 1952 resulted mainly from the lower topography factors used in the Browning Equation. In the estimates of farmers' goals, however, the increase in credit given to topography was more than offset by the decrease in credit given for special practices on steep slopes. Since one major component of farmers' goals for those years was the adoption of contour cultivation, there was a tendency to increase the soil loss estimate of farmers' goals by using the revised Browning Factors.

Changes in Observed Soil Losses,[16] Farmers' Goals and Program Goals

One of the objectives of this analysis was to determine the changes which have occurred in soil losses, farmers' goals and the program goals of erosion control in the Ida-Monona soil association. After revising the previous estimates of soil losses and farmers' goals of soil losses and making similar calculations for 1957, it was possible to compare the estimates for individual farms and the sample for 1949, 1952 and 1957.

CHANGES IN SOIL LOSS ESTIMATES SINCE 1949

A comparison of the observed soil losses as well as farmers' goals of erosion control in 1957 and 1949 is made in fig. 2. Both the curve of 1957 observed soil

[15] Use-capability classes are defined by the SCS according to the suitability of the land for cultivation and other uses (41, pp. 5-12).

[16] The term "soil loss" has been used in this analysis to mean the estimate of erosion computed by means of the Browning Equation. In no case was soil loss measured physically.

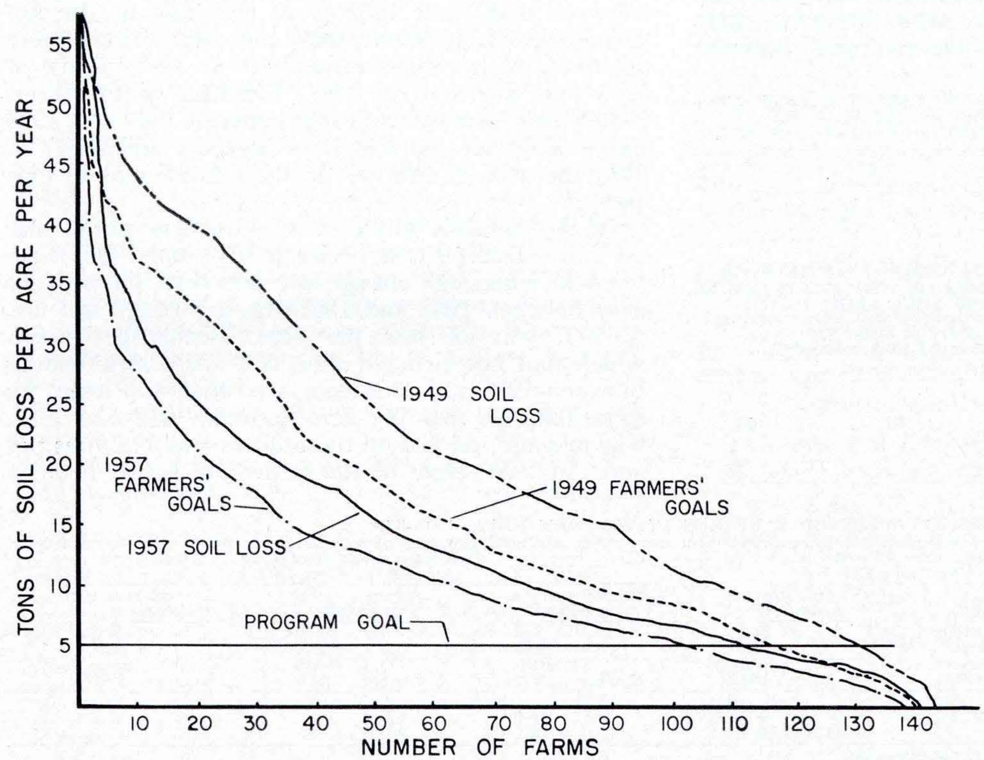

Fig. 2. Erosion losses on 138 farms in western Iowa arrayed according to decreasing soil loss in tons per acre shown in terms of the soil losses, farmers' goals of erosion control and program objectives, 1949 and 1957.

losses and the curve of 1957 farmers' goals lay beneath similar 1949 curves, with the exceptions of a few farms with extremely high soil losses. Consequently, both observed soil losses and farmers' goals of erosion control expressed in soil loss rates have decreased substantially in the intervening 8 years. Nevertheless, the horizontal line representing the program goal of 5 tons per acre soil loss has remained unchanged and below the soil loss estimates for most farms. Consequently, the first delimiting hypothesis—if the soil erosion losses in western Iowa are above the permissible rate of 5 tons of soil loss per acre per year, then certain obstacle situations exist that prevent this achievement—was accepted.

The estimates of the average soil loss in 1949, 1952 and 1957 are presented in table 3. Since the revised Browning Factors were used in calculating all three, the estimates are comparable. Although the decrease in soil loss means between 1949 and 1952 was only 1.6 tons, the decrease between 1952 and 1957 was 5.4 tons per acre. Consequently, substantial progress had been made toward reducing soil erosion in western Iowa. Nevertheless, the difference in soil loss rates between 1957 and the program's goal provided evidence for accepting the second delimiting hypothesis—if the present rate of soil loss exceeds society's goal, as past inquiries have indicated was the case, then the rate of change in the obstacle situations has not been as rapid as society desires.

Although the average soil loss was progressively lower in 1952 and 1957 than in 1949, soil losses did not decrease on every farm. Table 4 shows that between 1952 and 1957, rotations were responsible for decreases in soil losses of more than 5 tons per acre on 26 farms in the sample. On 21 farms, the adoption of special practices reduced soil losses, while the use of better management practices resulted in lower soil losses on 20 farms. On nine farms, however, more erosive management practices were adopted between 1952 and 1957. Likewise, on five farms the failure to continue use of special practices resulted in higher soil losses. And on seven farms the adoption of more intensive rotations by 1957 contributed to soil losses being at least 5 tons per acre higher than in 1952.

TABLE 3. SOIL LOSS ESTIMATES IN TONS PER ACRE CALCULATED WITH THE REVISED BROWNING FACTORS ON A SAMPLE OF FARMS IN WESTERN IOWA, 1949, 1952 and 1957.

Year	Annual soil loss mean
1949	21.1
1952	19.5
1957	14.1

TABLE 4. CHANGES IN EROSION-CONTROL PRACTICES ON A SAMPLE OF FARMS IN WESTERN IOWA ON WHICH SOIL LOSSES CHANGED BY AT LEAST 5 TONS PER ACRE FROM 1952-57.

	Number of farms where erosion factors changed		
Change in soil losses	Management	Special practices	Rotations
Soil losses lower by at least 5 tons per acre per year in 1957 and 1952	20	21	26
Soil losses higher by at least 5 tons per acre per year in 1957 and 1952	9	5	7

FARMS ON WHICH SOIL LOSSES CHANGED BY MORE THAN 5 TONS PER ACRE BETWEEN 1949 AND 1957

In 1952, Held and Timmons found that, although the average soil loss for the sample had decreased since 1949, there were some farms on which soil losses had increased. Similarly, there were farms where soil losses changed in both directions between 1952 and 1957. In table 5, farms are grouped according to their soil loss change if these changes were greater than 4.9 tons per acre between 1949 and 1952 or between 1952 and 1957. Between 1949 and 1952 there were 23 farms on which soil losses increased by at least that amount. The average 1952 soil loss on these farms was 33.5 tons per acre. Likewise, there were 36 farms on which soil losses decreased by more than 4.9 tons between 1949 and 1952. These farms had an average soil loss of 18.5 tons per acre in 1952. There were 78 farms with an average 1952 soil loss of 16.1 tons per acre on which the soil loss had not changed as much as 4.9 tons per acre since 1949.

On farms within each of the change groups between 1949 and 1952 there were additional changes in soil losses between 1952 and 1957. These farms also were classified into increase, no change and soil-loss-decrease groups, depending upon whether or not the soil-loss change was greater than 4.9 tons per acre between 1952 and 1957. Of the 23 farms which had increased soil loss more than 4.9 tons between 1949 and 1952 there were none on which soil loss was more than 4.9 tons per acre higher in 1957 than it had been in 1952. Five farms which had increased soil losses between 1949 and 1952 were classified in the no-change group between 1952 and 1957. These were relatively high-soil-loss farms with an average loss of 29.8 tons per acre in 1957. Eighteen of the farms which had increased soil loss between 1949 and 1952 decreased their soil loss between 1952 and 1957. In 1957 the average soil loss on these farms was 12 tons per acre.

Of the 78 farms on which soil losses had not changed more than 4.9 tons between 1949 and 1952, there were 41 where the change was less than 4.9 tons per acre between 1952 and 1957. Their average soil loss in 1957 was 9.6 tons per acre. Twenty-nine farms which had not changed their soil losses significantly between 1949 and 1952 decreased their soil losses by more than 4.9 tons per acre between 1952 and 1957. The average soil loss on these farms was 11.2 tons per acre. In 1957, eight of the farms which had been in

TABLE 5. TRENDS IN SOIL LOSSES ON A SAMPLE OF FARMS IN WESTERN IOWA, 1949-57.[a]

Soil loss change greater than 4.9 tons per acre between 1949 and 1952						Soil loss change greater than 4.9 tons per acre between 1952 and 1957					
Soil loss increased		No change		Soil loss decreased		Soil loss increased		No change		Soil loss decreased	
Number	Soil loss mean 1952	Number	Soil loss mean 1952	Number	Soil loss mean 1952	Number	Soil loss mean 1957	Number	Soil loss mean 1957	Number	Soil loss mean 1957
23	33.5					..	..	5	29.8	18	12.0
		78	16.1			8	28.2	41	9.6	29	11.2
				36	18.5	9	28.9	20	14.8	7	11.6

[a] The record from one farm for 1952 was not available.

the 1949-52 no-change classification increased their soil losses more than 4.9 tons per acre between 1952 and 1957. The mean soil loss for these farms was 28.2 tons per acre in 1957.

Of the 36 farms on which soil losses had decreased between 1949 and 1952, 20 did not change soil losses by more than 4.9 tons per acre between 1952 and 1957. Their mean soil loss of 14.8 tons per acre was slightly above the over-all sample mean. Nine farms on which soil losses had decreased between 1949 and 1952 increased soil losses by more than 4.9 tons per acre between 1952 and 1957. On these farms soil loss averaged 28.9 tons per acre in 1957. Of the 36 farms on which soil losses had decreased between 1949 and 1952, seven continued to decrease soil losses by more than 4.9 tons between 1952 and 1957. This group of seven farms had an average soil loss of 11.6 tons per acre in 1957. Consequently, there have been changes in soil losses both up and down since 1949.

CHANGES IN FARMERS' GOALS AND IN PRACTICES TO ATTAIN THE PROGRAM GOAL

Estimates of farmers' goals of erosion control for the sample of farms in western Iowa are presented in table 6. Although the mean was slightly higher in 1952 than in 1949, there was a substantial improvement in farmers' goals between 1952 and 1957, as expressed by a decrease in tons of soil loss. The decrease from 16.7 tons per acre in 1952 to 11.7 tons per acre in 1957 indicated that there has been substantial improvement in farmers' awareness of the problem.

TABLE 6. FARMERS' GOALS OF EROSION CONTROL ESTIMATED IN TONS OF SOIL LOSS PER ACRE FOR A SAMPLE OF FARMS IN WESTERN IOWA, 1949, 1952 AND 1957.

Year	Farmers' goals of erosion control (soil loss mean in tons per acre)
1949	16.4
1952	16.7
1957	11.7

Although the program goal remained constant at 5 tons per acre per year, there had been changes in the practices recommended to achieve the goal. As a result of the changes in the value of the Browning Factors, SCS technicians recommended more mechanical practices and a higher proportion of row crops with mechanical practices than in 1949 and 1952. When few mechanical practices were used and the bulk of the erosion-control responsibility rested with high-forage rotations, however, there was little change in the practices recommended to achieve the soil-erosion-control goal.

The percentage of all land in the sample recommended for row crops in the mechanical-practices plan increased from 21.6 in 1949 and 1952 to 33.4 in 1957, as shown in table 7. There was a corresponding

TABLE 7. PROPORTION OF ACREAGE BY TYPES OF CROPS RECOMMENDED BY THE SOIL CONSERVATION SERVICE ON A SAMPLE OF FARMS IN WESTERN IOWA, 1949, 1952 AND 1957.

Land use	Mechanical-practices plan		High-forage-rotation plan	
	1949-52 (percent)	1957 (percent)	1949-52 (percent)	1957 (percent)
Row crops	21.6	33.4	14.6	16.7
Small grain	15.9	19.2	15.5	16.8
Meadow	37.7	30.1	41.6	39.5
Permanent pasture	15.3	8.1	14.7	17.4
Other	9.5	9.2	13.6	9.6
Total	100.0	100.0	100.0	100.0

increase in the percentage of small grains recommended and a decrease in meadow and permanent pasture recommended in the mechanical-practices plans. In contrast, there was little change in the land use recommended in high-forage rotation plans for 1957, relative to 1949 and 1952. Consequently, high-forage rotation plans remained essentially the same in 1957 as they had been in the earlier studies. We expected that these changes in recommendations would have a substantial effect on the obstacles to the adoption of soil-erosion-control practices. Since research made it possible to recommend practices more nearly like those already on farms in the area, we anticipated fewer obstacles to the practices.

Erosion-Control Practices on Farms and Operators' Reactions to Additional Practices

With given physical soil characteristics, soil erosion can be reduced only through the adoption of erosion-control practices—rotations, management or special practices. Practices on farms are responsible for soil losses being as low as they are.

ESTABLISHED AND RECOMMENDED EROSION-CONTROL PRACTICES

The number of farms on which individual erosion-control practices were recommended, the number of farms on which practices were used in 1957 and the number of farmers who objected to each practice are given in table 8. On 100 of the 138 farms, some waterways were being used in 1957. On these 100 farms, waterways were not necessarily established to the extent of or according to the specifications recommended by the Soil Conservation Service. On 86 of the farms, at least some contouring was being used in 1957. Of the mechanical practices listed in table 8, there were fewer farms on which terraces had been adopted than had adopted any other practice. On more than 60 percent of the farms, no terraces were established. Eighty-three farm operators objected to some or all of the terraces recommended in Plan I prepared by the SCS personnel. The number of farm operators objecting to this practice was exceeded only by the 99 farm operators who objected to high-forage rotations in 1957. There was less objection to contouring than to any other practice. All six practices listed in table 8 were recommended for every farm in the sample, with the exception of terracing, which was not recommended for one farm.

OBSERVED AND RECOMMENDED LAND USE

The observed land use on farms in the sample in 1949, 1952 and 1957 and that recommended in Plan

TABLE 8. NUMBER OF FARM OPERATORS WHO WERE FOLLOWING AND THOSE WHO OBJECTED TO EROSION CONTROL PRACTICES ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Practice	Number of farms where practice was recommended in farm plans	Number of respondents who were using practice	Number of respondents who objected to practice in farm plans
Contouring	138	86	22
Terracing	137	55	83
Waterways	138	100	29
Fertilizer	138	65	48
High row-crop rotation	138	...	71
High forage rotation	138	...	99

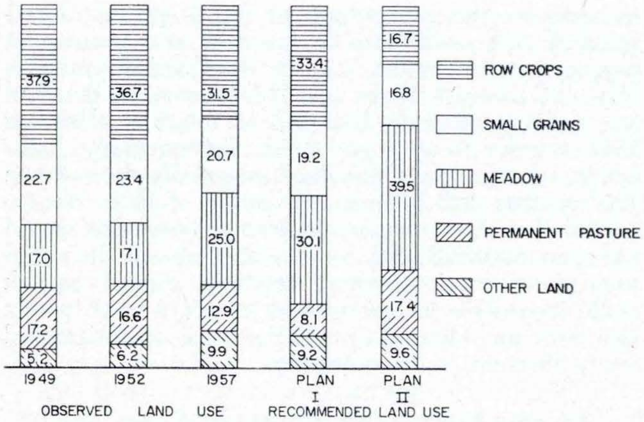

Fig. 3. Percentage of total land in a sample of western Iowa farms in various uses, 1949, 1952, 1957 and use recommended by the Soil Conservation Service in 1957—Plan I (mechanical practice plan) and Plan II (high forage rotation plan).

I and Plan II in 1957 are presented in percentage form in fig. 3. Although the percentage of land in row crops decreased from 1949-57, it was still larger than that recommended in Plan II, but slightly less than recommended in Plan I. The percentage of land in meadow increased from 1949-57, but it was less than that recommended in both Plan I and Plan II. While the land use in 1957 appeared similar to that recommended in Plan I, there were several additional considerations included. Although the percentage of row crops was slightly less in 1957 than recommended in Plan I, this did not mean that the row crops were located on the soil areas recommended by SCS personnel. Also, terraces were recommended in Plan I to reduce soil loss to a permissible level in conjunction with this amount of row crops. Finally, the percentage of row crops varied annually and partially depended upon the government program in existence in any particular year. Changes in programs similar to the change in federal price-support programs between 1957 and 1960 might be expected to increase the amount of land in erosive intertilled crops. Consequently, the land use observed in 1957 should not be interpreted as an indication of permanent achievement of land use which will reduce soil loss to the program goal.

TABLE 9. NUMBER OF FARMS WHERE OPERATORS' REACTIONS WERE CLASSED AS OBSTACLES TO SOIL-EROSION-CONTROL PRACTICES, ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Obstacle	Number	Annual soil loss mean (tons per acre)
Amound or kind of recommended practice	90	14.2
Need for immediate income	70	17.4
Insufficient roughage-consuming livestock	51	18.0
Failure to see the need for a recommended practice	47	16.6
Custom and inertia	33	18.6
Rental arrangement and lack of landowner's cooperation	25	17.2
Field and road layout	22	17.0
Lack of adequate machinery and power	17	17.7
Short expectancy of tenure	12	16.6
Lack of cooperation of neighboring farmers	12	12.2
Terrace design	10	11.7
Small size of farm	10	14.5
Lack of adequate labor supply	8	12.6
Risk and uncertainty	8	16.7
Lack of adequate buildings	4	17.2
Ability to shift erosion losses	1	13.8
Price change expected	0	...
Lack of availability of credit	0	...

EXPLANATION OF FACTORS RESPONSIBLE FOR VARIATION IN SOIL LOSSES AND CHANGES IN SOIL LOSSES

The observed soil losses varied substantially with obstacles and socio-economic characteristics of the sample farms. One of the primary objectives of the analysis was to detect significant cause and effect relationships among these variables. A variety of statistical techniques was used to determine which causal factors, either success or failure elements, were responsible for variation in soil loss. The 95-percent level of probability was accepted as the level of statistical significance.

Failure Elements Causing Soil Losses Greater Than the Program Goal in 1957

Since soil losses on most farms in the sample were greater than the program goal of 5 tons per acre, a major portion of the analysis was devoted to an investigation of the failure elements. Effects of both observed characteristics and reported obstacles on the sample farms were analyzed.

On those farms where the operator objected to an erosion-control practice in one of the farm plans, he was asked to give his reasons for objecting. In addition to the initial response given by the operator when the farm plans were presented to him, a detailed explanation was sought for the objection.

TABLE 10. NUMBER OF FARM OPERATORS WHO REPORTED OBSTACLES TO INDIVIDUAL EROSION-CONTROL PRACTICES AND NUMBER OF FARMS ON WHICH EACH OBSTACLE WAS REPORTED, 138 FARMS IN WESTERN IOWA, 1957.

Obstacle	Number of operators who reported obstacles to specified practices								Farms on which obstacle was reported
	Con-touring	Ter-racing	Water-ways	Ferti-lizer	Struc-tures	Contour fencing	Plan I	Plan II	
Amount of kind of recommended practice	3	39	3	8	0	3	59	38	90
Need for immediate income	0	9	7	25	6	1	9	47	70
Insufficient roughage-consuming livestock	0	0	0	0	0	1	15	49	51
Failure to see the need for recommended practice	12	31	9	16	1	18	0	0	47
Custom and inertia	6	14	3	10	0	1	18	10	33
Rental arrangment and lack of landowner's cooperation	2	16	4	6	2	1	4	10	25
Field and road layout	10	5	0	0	0	13	2	2	22
Lack of adequate machinery and power	5	10	0	0	0	0	1	3	17
Short expectancy of tenure	3	5	3	10	3	5	3	3	12
Lack of cooperation of neighboring farmers	0	1	10	0	1	0	0	0	12
Terrace design	0	10	0	0	0	0	0	0	10
Small size of farm	0	1	0	0	0	0	3	9	10
Lack of adequate labor supply	0	1	0	0	0	3	1	3	8
Risk and uncertainty	0	1	0	3	0	0	0	5	8
Lack of adequate buildings	0	0	0	0	0	0	0	4	4
Ability to shift erosion loss	1	0	0	0	0	0	0	0	1

CLASSIFICATION OF OBJECTIONS TO FARM PLANS AS OBSTACLES PREVENTING PRACTICE ADOPTION

During the course of the interview, each farm operator's objections to specific erosion-control practices recommended by SCS were classified as one or more of the hypothesized obstacles which might prevent the adoption of erosion-control practices. One or more farm operator's responses were classified in 16 of the 18 hypothesized obstacles. These obstacles, the number of farmers whose response was classified within each and the soil loss mean for farms with each obstacle are presented in table 9.

In table 10, the number of farm operators who expressed obstacles to specific erosion-control practices is presented. The total number of farms on which each obstacle appeared is given also. The total number of farms with each obstacle is equal to or less than the sum of the farms with obstacles to specific practices. This possible difference was due to some operators indicating that an obstacle could have prevented the adoption of more than one erosion-control practice.

STATISTICAL TESTS OF THE EFFECTS OF OBSTACLES ON SOIL LOSSES

Since the average annual soil loss for farms with each obstacle deviated from the over-all sample soil loss mean, several statistical procedures were used to determine whether the variations in soil loss associated with obstacles might have been due to chance. Table 11 shows the results of the statistical tests. Initially, a "t" test was performed to determine whether the difference in soil loss means between farms with and without each obstacle was significant. This procedure necessitated the assumptions (1) that the method of sampling had no effect on the observed soil losses and (2) that there were no interrelationships among obstacles. The difference between the soil loss means for farms with and without the obstacles of need for income, custom and inertia and insufficient roughage-consuming livestock were significant at the 99-percent level of probability. Although not statistically significant, the obstacle of failure to see the need for a recommended practice was responsible for differences in soil loss means having been greater than zero at the 90-percent level of probability.

Another series of "t" tests was performed to determine the statistical significance of the difference in soil loss means for farms with and without each obstacle while considering the sampling procedure in estimating the variance of the differences of the means. This procedure was followed for two reasons. First, it was the statistical procedure used by Frey (14) in a previous analysis in the series, and comparison of results between the two analyses necessitated use of similar methods. Second, an analysis of variance indicated that strata were significant at the 99-percent level of probability in explaining differences among soil losses in the sample. The mean square among strata divided by the mean square within strata yielded: $239.9/96.6 = 2.48^{**}$[17] $= F$. Therefore, both continuity of method and the significant effect of strata in explaining soil losses necessitated including consideration of the method of sampling.

The tests performed on the soil loss means, when the sampling procedure was considered in estimating the variance of the means, resulted in "t" values which were significant at the 95-percent level of probability for the following obstacles: need for immediate income, custom and inertia, failure to see the need for recommended practices, insufficient roughage-consuming livestock, the rental arrangement and lack of landowner's cooperation, lack of adequate buildings, lack of cooperation of neighboring farmers, lack of adequate labor supply and short expectancy of tenure. Of these 10 obstacles, Frey found that short expectancy of tenure, need for immediate income, rental arrangement and lack of landowner's cooperation and insufficient roughage-consuming livestock were statistically significant in explaining differences in soil loss means on the same sample of farms in 1949.

The test for differences in soil loss means which included consideration for the sampling procedure had two limitations. First, the procedure failed to consider the possible covariance between farms with each obstacle and those without it. Second, the statistical determination did not consider the possible interrelationships among obstacles in their effects on soil losses.

[17] The 99-percent level of probability is indicated by ** and the 95-percent level by *.

TABLE 11. RESULTS OF STATISTICAL TESTS TO DETERMINE THE PROBABILITY THAT THE AVERAGE SOIL LOSS ON FARMS WHERE AN OBSTACLE WAS PRESENT WAS DIFFERENT FROM THE AVERAGE SOIL LOSS ON FARMS WITHOUT THE OBSTACLE BECAUSE OF A REASON OTHER THAN CHANCE ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Obstacle	Level of probability		
	"t" tests of the soil loss mean disregarding sampling procedure[a]	"t" tests of the soil loss mean considering sampling procedure[b]	"t" tests of the regression coefficients[b]
Need for immediate income	0.99**	0.99**	0.99**
Custom and inertia	0.99**	0.99**	0.97*
Failure to see the need for recommended practice	0.90	0.99**	0.97*
Insufficient roughage-consuming livestock	0.99**	0.99**	0.50
Rental arrangement and lack of landowner's cooperation	0.80	0.99**	0.80
Lack of adequate buildings	0.50	0.99**	0.90
Field and road layout	0.80	0.60	0.95*
Risk and uncertainty	0.50	0.99**	0.50
Lack of cooperation of neighboring farmers	0.50	0.99**	0.50
Lack of adequate labor supply	0.50	0.95**	0.60
Short expectancy of tenure	0.50	0.99**	0.50
Lack of adequate machinery and power	0.80	0.80	0.60
Terrace design	0.50	0.60	0.50
Amount or kind of recommended practice	0.50	0.50	0.50
Small size of farm	0.50	0.50	0.50
Ability to shift erosion losses	0.50	0.50	0.50

[a] Snedecor has described the procedure for computing the variance of unequal size groups (38, pp. 90-91).
[b] See Appendix D for an explanation of the tests of significance.
** Significant at the 99-percent level of probability.
* Significant at the 95-percent level of probability.

To overcome these limitations, a regression analysis also was used.

In the multiple variable regression equation, soil loss was used as the dependent variable, while obstacles and a topographic index were used as independent variables. The relationship between topographic classes and soil loss is shown in fig. 4. Inclusion of a topographic index as an independent variable was logical when the Browning Equation for estimating soil losses was considered. The obstacles analyzed affected only the adoption of erosion-control practices. In the Browning Equation, these practices are in addition to the physical variables (percent of slope, length of slope, degree of erosion and soil type) used in estimating soil losses. Therefore, obstacles are related only indirectly to topography, which should be included in evaluating the effects of the obstacles.

Before accepting the regression equation used in testing the hypotheses that each obstacle had no effect in determining soil losses, several changes were made in the regression model. Initially, a multiple variable regression analysis was computed with soil loss as a function of obstacles plus topography, disregarding the level of soil loss on farms where obstacles occurred and whether there were obstacles to both SCS plans. This resulted in a coefficient of multiple determination, R^2, of 0.496. The independent variables of topography, need for immediate income, rental arrangement and lack of landowner's cooperation, and custom and inertia were accepted as statistically significant because the null hypothesis that each had no effect on soil losses was rejected at the 95-percent level of probability.

A more thorough analysis of the simultaneous effects of obstacles on soil losses necessitated several additional considerations. First, obstacles to specific erosion-control practices were considered as obstacles preventing the reduction of soil loss for the entire sample. Since the practices to which the obstacles were expressed constituted two alternative erosion-control farm plans, an obstacle was not considered effective in preventing the reduction in soil loss unless there were obstacles to at least one practice in each of the plans. Second, obstacles were observed on farms where erosion losses had been reduced below the 5-ton per acre public goal. These obstacles to specific practices were not considered relevant in explaining the soil loss gap between the present situation and the program's goal.

Embracing these refinements, a second regression equation was computed using soil loss as a function of topography plus effective obstacles. This calculation resulted in an R^2 of 0.511. Topography and the obstacle of need for immediate income were the only two independent variables statistically significant at the 95-percent level of probability.

A third function was fitted by multiple variable linear regression with soil loss as a function of topography and effective obstacles. In this case, only 111 farms were included on which there were effective obstacles. A coefficient of multiple determination of 0.453 was obtained. The independent variables of topography and obstacle of need for immediate income had sample regression coefficients significant at the 95-percent level of probability.

The final equation fitted by multiple variable linear regression was a result of information gained from the prior calculations. In addition to the three multiple variable linear regression problems just discussed, multiple correlation calculations were made for each variation of the regression model. They yielded information concerning the intercorrelation among variables used in the regression analyses. Since the obstacles of custom and inertia and failure to see the

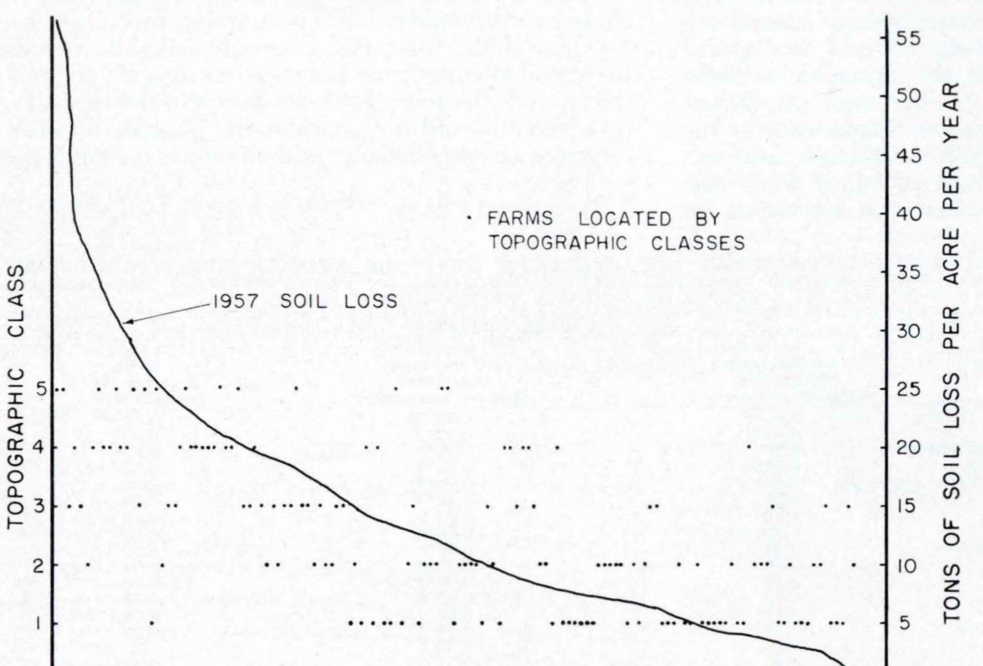

Fig. 4. Soil losses on 138 farms in the Ida-Monona soil association arrayed according to decreasing soil loss per acre and topographic class of each farm, 1957.

need for recommended practices were highly intercorrelated, they were redefined and combined in a new obstacle. This was done after consideration was given to the similarity of operators' responses classified within each obstacle.

The final regression equation was calculated with soil loss as the dependent variable and topography plus effective obstacles as independent variables. Observations for the entire sample of 138 farms were included in the topography variable, but an obstacle for an individual farm was included only if the soil loss on the farm was greater than 5 tons per acre and if there were obstacles to both SCS plans. Since the observations on obstacles were included in the input of the regression problem as 1's if the obstacle were present and zeros if it were not, all farms with soil losses below 5 tons and without obstacles to both SCS plans had zeros entered for the obstacle variables.

Before the final regression equation (the results of which are presented in table 11) was accepted for explaining the effect of obstacles on soil losses, several additional calculations were performed. Inclusion of the topography variable was expected to explain most of the variation in soil losses which occurred because of the sampling procedure. Since stratified proportional cluster sampling yielded groups of farms which tended to have similar topography within clusters, some of the variation in soil loss resulting from topography might have been explained by the sampling procedure. To test whether topography and the most important obstacles explained the effect of the strata, a multiple variable linear regression equation was calculated for soil loss as a function of 23 strata and topography, plus the obstacles of need for immediate income, field and road layout, failure to see the need for recommended practices—custom and inertia, and the rental arrangement and lack of landowner's cooperation.[18] The regression equation also was recalculated with the 23 strata variables omitted.

According to the procedure described by Anderson and Bancroft (1, p. 172), an F ratio was calculated to determine whether the difference in variation explained by the two regression equations was significant at the 95-percent level of probability. The calculations yielded $F=1.06$, which, with the appropriate degrees of freedom, is not significant. Hence, it was concluded that topography plus the three obstacles which were statistically significant in the final regression equation sufficiently explained the variations in soil losses which might have been explained by the strata.

One additional computation was performed prior to acceptance of the final regression equation. The final regression equation was recalculated, dropping successive variables until the difference in variation explained by regression in the abbreviated equation and the over-all model was statistically significant at the 95-percent level of probability. The F ratios indicated that all variables, other than those with significant sample regression coefficients in the final equation, could be deleted from the regression equation without the difference in variation explained by the regressions being statistically significant. The coefficient of multiple determination for the reduced variable regression equation (soil loss as a function of topography plus the three obstacles with significant sample regression coefficients in the over-all model) was 0.486. Hence, the over-all regression equation,[19] the results of which are recorded in table 11, was accepted.

The over-all regression model yielded a coefficient of multiple determination, R^2, of 0.522. The F test to determine whether the variation explained by regression was greater than zero was performed by dividing the mean square due to regression by the mean square deviation from regression (37, p. 417). In this case, $F=539.69/65.29=8.27^{**}$. Consequently, with the appropriate degrees of freedom, the variation explained by regression was significant at the 95-percent level of probability or above. Also, four independent variables—obstacle of need for immediate income; obstacle of failure to see the need for recommended practices, custom and inertia; obstacle of field and road layout; and topography — had sample regression coefficients larger than those expected at the 95-percent level of probability when "t" tests were performed on them.

Therefore, the first diagnostic hypothesis—if the soil losses exceed the 5-ton-per-acre limit, then certain obstacles are responsible—was accepted with respect to the three statistically significant obstacles. The obstacles which were not statistically significant could not be entirely ignored for two reasons. First, many of the obstacles have persisted near levels of statistical significance over time. Second, the interrelationships between these obstacles and those that were statistically significant may indicate possible measures for alleviating the most important obstacles.

Characteristics of Farms and Farm Operators and Their Effect on Erosion Control

In a further effort to determine factors associated with soil losses, socio-economic characteristics of the sample farms were observed and analyzed. A wide variety of characteristics was found on the sample farms.

TENURE OF FARM OPERATORS

Since investments in soil-erosion-control practices

[18] One of the 24 strata had to be omitted from the regression equation to allow for enough degrees of freedom to make computation of the problem possible. Farms within each strata were entered in the regression problem as 1's, while those not in each strata were entered as zeros, similar to the procedure for entering obstacles in the problem.

[19] The final regression equation for which the significant levels of the regression coefficients are presented in table 11 was:

$$Y = -1.95 - 1.50x_1 + 3.48x_2 - 1.78x_3 + 7.23x_4^{**} - 2.29x_5 + 5.34x_6^{*} - 0.61x_7 + 0.54x_8 + 8.80x_9 - 4.15x_{10} + 0.50x_{11} + 4.09x_{12} - 8.04x_{13} + 4.14x_{14}^{*} + 0.82x_{15} + 4.45x_{16}^{**}$$

where

x_1 = insufficient roughage-consuming livestock,
x_2 = rental arrangement and lack of landowner's cooperation,
x_3 = small size of farm,
x_4 = need for immediate income,
x_5 = lack of adequate machinery and power,
x_6 = field and road layout,
x_7 = short expectancy of tenure,
x_8 = risk and uncertainty,
x_9 = lack of adequate buildings,
x_{10} = lack of adequate labor supply,
x_{11} = lack of cooperation of neighboring farmers,
x_{12} = ability to shift erosion losses,
x_{13} = amount or kind of recommended practice,
x_{14} = failure to see the need for recommended practice—custom and inertia,
x_{15} = terrace design and
x_{16} = topographic index.

frequently yield returns over long periods of time, the type of tenure arrangement which provides long tenure, hence providing the expectation of gaining returns on the investment, might be expected to result in low soil losses.

The modal tenure group was owner-operator; however, part-owners had a lower average soil loss than the other two tenure classes, as shown in table 12. One possible reason for the lower soil loss mean for part-owners is that soil loss was computed on the headquarter farm only. In most cases, the headquarter farm was owned and the additional acreage rented. Part-owners who maximize their profits in the short run can be expected to minimize soil erosion on the owned segment and deplete the rented acreage. These interspatial disassociations of costs and benefits of erosion control might have resulted in higher soil losses on the additional acreage than on the headquarter farm of part-owners. Tenant-operated farms had a soil loss mean of 15.4 tons per acre, which was the highest of any tenure class. Since 1-year leases limited the planning horizon of many tenant-operators, the relatively high soil loss mean was not surprising.

TABLE 12. OPERATORS WITH VARIOUS TYPES OF TENURE ON ALL LAND OPERATED AND CORRESPONDING SOIL LOSSES ON A SAMPLE OF HEADQUARTER FARMS IN WESTERN IOWA, 1957.

Tenure	Number	Annual soil loss mean (tons per acre)
Owner	68	14.0
Part-owner	17	10.6[a]
Tenant	53	15.4
Total	138	14.1

[a] Limited to headquarter farms in the sample.

The proportion of owner-operators listed in table 12 is higher than that listed in table 1 for western Iowa. Part of this difference is due to the criteria used for tenure classification. On several farms in the sample in the Ida-Monona soil association area, the owner lived on the farm but field-rented all or part of his cropland to neighbors. Since the criteria for classifying tenure depended upon the extent of major managerial decisions made at the headquarters, these farms were classified as owner-operated. The criteria for classifying farms on the basis of operators of land, used in table 1, would have classed these farms as tenant- rather than owner-operated. Also, table 1 reports tenure of farms not only in the Ida-Monona soil association but also in other soil associations in the three crop reporting districts of western Iowa.

SIZE OF FARM

The distribution of sample farms according to size classes of the headquarter farms is presented in table 13. The corresponding average soil losses for each class also are listed. The most frequently occurring class included farms between 141 and 180 acres. The average soil loss for this group, 15.9 tons per acre, is 1.8 tons higher than the mean for the entire sample. The average size of farm, 172 acres, falls within the modal size class. Thus, the average size of the headquarter farms was 12 acres smaller than the average size of farms in western Iowa as indicated in table 1. Inclusion of land operated in addition to the headquarter farms would have provided a more direct comparison.

TABLE 13. SOIL LOSSES BY ACREAGE CLASSES ON A SAMPLE OF HEADQUARTER FARMS IN WESTERN IOWA, 1957.

Size classes (acres)	Number	Annual soil loss mean (tons per acre)
Less than 60	3	26.5
61-100	18	12.5
101-140	26	14.1
141-180	51	15.9
181-220	12	10.9
221-260	12	15.5
261-300	7	11.9
Greater than 300	9	6.5
Total	138	14.1

The lack of a clearly discernable trend in soil losses with changes in farm size was of interest. The need for income might not be expected to force as intensive land use on large farms as on small ones; however, only sample farms larger than 260 acres appeared to have been large enough to have avoided the pressure for immediate income.

The distribution of sample farms by type of tenure, corresponding size of headquarter farms and average acreage of all land operated are presented in table 14. For the 138 farms in the study, the average acreage of headquarter farms was 172 acres, while 214 acres was the average size of all land operated. The group with largest frequency was owner-operated. In this case, farms were classified by tenure on headquarter farms, thus some of the owner-operators of sample farms were part-owners with regard to all land operated. The average size of headquarter farms and all land operated for the owner-operator group was approximately the same as the average for the entire sample.

TABLE 14. NUMBER, AVERAGE ACREAGE OF HEADQUARTER FARMS AND AVERAGE ACRES OF ALL LAND OPERATED BY TENURE GROUPS ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Tenure	Number	Headquarter farms (mean acres)	All land operated (mean acres)
Owner	82	170	211
Tenant			
Cash-crop share	28	175	233
Crop-livestock share	18	199	232
Crop share	5	164	217
Cash	3	120	120
Other	2	73	73
Total	138	172	214

Among tenants, cash-crop share leases occurred most frequently. Also they had the largest total acreage operated, on the average. The second most frequently occurring type of lease was crop-livestock share. The 18 farms operated under this type of tenure arrangement had the largest total acreage of headquarter farms of any tenure classification in the sample.

AGE OF OPERATOR

In the early phases of the farm business cycle, the pressure for income to meet operating and investment expenditures might be expected to necessitate intensive use of the land, resulting in high soil losses. By contrast, as a farm operator becomes older the pressure for income might be expected to decrease. Running counter to these expectations might be young farmers' relatively long planning horizons which encourage erosion-control investments.

The distribution of farms in the sample according to age classes of operators is presented in table 15. There were more farms in the sample whose operators were within the class of 41 to 45 years of age than in any other class. The soil losses on these farms averaged higher than in any other age class with the exception of the 20-to-25-year class. The latter included just two operators. Only on those farms whose operators were above 55 years was there any apparent trend of decreasing soil loss with increasing age of operator.

TABLE 15. AGE OF OPERATORS AND SOIL LOSSES ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Age classes (years)	Number	Annual soil loss mean (tons per acre)
20-25	2	39.8
26-30	10	14.3
31-35	19	12.1
36-40	16	15.3
41-45	21	16.2
46-50	20	13.8
51-55	19	15.8
56-60	9	12.7
61-65	12	10.7
66 and over	10	8.3
Total	138	14.1

TYPE OF FARM

Farms in the sample were characteristic of the agricultural economy in the Ida-Monona soil association area. Twenty-eight percent of the farms in the sample were classed as cattle feeding and hog farms. The average soil loss on these farms was 8.4 tons per acre lower than the next most frequently occurring type of farm. Twenty-seven farms which received most of their income from hogs and corn were included in the second largest group. Seventeen percent of the farms in the sample had cash grain as a major source of income, while 11 percent of them were general farms. They had soil losses of 14.4 and 13.9 tons per acre on the average, respectively.

TABLE 16. SOIL LOSSES, PERCENT AND NUMBER OF FARMS BY TYPE ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Type of farm	Number	Percent of 138 sample farms	Annual soil loss mean (tons per acre)
Cattle feeding and hogs	39	28	10.5
Hogs and corn	27	20	18.9
Cash grain	24	17	14.4
General	16	11	13.9
Hogs and cream	9	7	19.0
Cattle feeding	6	4	10.2
Dairy	4	3	14.7
Beef cows and calves	4	3	15.9
Beef cattle and hogs	4	3	10.9
Other	5	4	13.5
Total	138	100	14.1

Although there was substantial deviation of the soil loss means by type of farm (table 16), there did appear to be a trend present. Soil losses on farms where the major source of income was from forage-consuming livestock were expected to be less than on other farms. On farms where the main enterprise was cattle feeding and hogs, cattle feeding, dairy, beef cows and calves, and beef cattle and hogs, the soil loss means fell below those farms where forage-consuming livestock did not represent the main source of income.

FARM OPERATORS' PARTICIPATION IN GOVERNMENT PROGRAMS

Three government programs principally affected erosion control on participating farms in the Ida-Monona soil association area in 1957. They were the soil bank, the Agricultural Conservation Program and the Soil Conservation District Program. Although the acreage reserve of the soil bank was an income transfer and supply control measure, it also tended to reduce soil erosion. This was accomplished by payments to farmers to shift land from row crops to forage crops in the year that the land was rented by the federal government. The Agricultural Conservation program paid farmers to adopt "conservation" measures. The Soil Conservation Service, functioning through the Soil Conservation District Program, offered technical assistance and aided farmers in planning their business to facilitate the reduction of soil erosion.

TABLE 17. NUMBER OF ACRES IN ACREAGE RESERVE AND SOIL LOSSES BY TENURE GROUPS ON 47 FARMS PARTICIPATING IN THE SOIL BANK IN A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Tenure	Number	Mean acres per farm in acreage reserve	Annual soil loss mean (tons per acre)
Owner	30	39	9.3
Part-owner	5	32	11.6
Tenant	12	68	9.4
Total	47	46	9.6

As shown in table 17, only 47 of the 138 farms had any land in the acreage reserve of the soil bank in 1957. Moreover, a relatively small proportion of the land in these farms was in the soil bank. Although the average soil loss for farms with land in the soil bank was 9.6 tons per acre, compared with the average soil loss of 16.4 tons per acre for farms not participating in the soil bank, it was questionable whether soil bank participation was the principal reason for this difference in soil loss means. Soil bank participation entered into the soil loss estimates through the rotation variable in the Browning Equation. Although this variable was affected by land use in 1957, it was also affected by the sequence of crops within the whole rotation. Consequently, a shift from a year of row crops to a year of meadow in a 5- or 6-year rotation had a relatively small effect on soil loss estimates. Therefore, there were additional factors besides soil bank participation which resulted in relatively lower soil losses for these farms than others in the sample.

On 84 of the 138 farms, the farm operators did not complete an ACP practice in 1957 for which they received payment (table 18). The average soil loss on these farms was 1 ton above the average of 14.1 tons for the entire sample. The most frequently adopted ACP practice was temporary seeding. On 23 farms this practice was completed; their average soil loss was 10.2 tons per acre. Other ACP practices in 1957 were completed on few farms in the sample. The numbers of farms on which permanent erosion-control practices such as terracing, waterways and permanent seeding were completed were conspicuous by their low frequency. This can be explained partially

TABLE 18. NUMBER OF FARM OPERATORS RECEIVING PAYMENTS FOR ONE OR MORE AGRICULTURAL CONSERVATION PROGRAM PRACTICES AND AVERAGE SOIL LOSSES ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.[a]

Practice	Number	Annual soil loss mean (tons per acre)
None	84	15.1
Temporary seeding	23	10.2
Contouring	3	17.6
Terracing	3	21.8
Waterways	3	11.1
Pasturing data	3	10.6
Waterways and terraces	3	9.6
Permanent seeding	2	12.9
Other	12	12.8

[a] This information was obtained through private communication with Agricultural Stabilization Committee offices in the Ida-Monona Soil Association, 1959.

TABLE 19. NUMBER OF FARMS AND AVERAGE SOIL LOSSES BY SOIL CONSERVATION DISTRICT COOPERATION CLASSES ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

SCD cooperation	Number	Annual soil loss mean (tons per acre)
Complete farm plan	46	10.3
Initial farm plan	23	14.7
Noncooperator	69	16.5
Total	138	14.1

by the unfavorable weather and the cost-price squeeze preceding 1957, both of which limited the ability of farm owners to pay their portion of the cost-sharing practices.

The sample farms are classed according to their cooperation with soil conservation districts in table 19. On the 46 farms which had complete farm plans, average soil loss was 10.3 tons per acre. Although these farmers had made substantial progress in reducing their soil losses below the average in the area, their losses still exceeded those called for in their farm plans by 5.3 tons per acre. On 23 farms where initial farm plans were in effect, the average soil loss was 14.7 tons per acre. These initial plans were primarily informal and resulted mainly from technical assistance given the farm operator by SCS personnel in conjunction with the Agricultural Conservation Program. On 69 farms, the farm operator was classified as not cooperating in any way with soil conservation districts. On these farms, the average soil loss was 16.5 tons per acre in 1957.

In addition to planning farms and supplying technical assistance, the SCS had been active in initiating watershed programs under Public Law 566. In 1957 there were only 12 of the 138 farms participating in watersheds (table 20). Their average soil loss of 16.9 tons per acre was illustrative of the erosion problem on these farms. Recognition of this problem may have caused these operators to participate in the program.

TABLE 20. NUMBER OF FARM OPERATORS PARTICIPATING IN ORGANIZED WATERSHEDS AND THE AVERAGE SOIL LOSSES ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Watershed participation	Number	Annual soil loss mean (tons per acre)
Participating	12	16.9
Not participating	126	13.8
Total	138	14.1

CHANGES IN CHARACTERISTICS OF THE SAMPLE FARMS BETWEEN 1949 AND 1957

Numerous characteristics of the sample farms changed between 1949 and 1957. Those expected to be most important were analyzed to determine their effects on soil losses.

Changes of farm operators are likely to have an effect on soil losses. Operators on farms where there has been a frequent turnover might have relatively short planning horizons, particularly if the operator were a tenant. Furthermore, several years usually are required before an operator is able to adopt a comprehensive erosion-control plan.

Operators on farms for 5 years or less had an average soil loss of 15.9 tons per acre in 1957. There were 47 farm operators within this category. There were only 14 farms on which the operator had been interviewed in 1952 and 1957; therefore only 14 had initiated their operations between 1949 and 1952. The average soil loss for this group was 12.6 tons per acre in 1957. The group in which operators had been present since 1949 included 77 farm businesses on which the average soil loss was 13.3 tons per acre in 1957. Consequently, a rather irregular trend indicated that the longer operators had been on farms the lower soil losses tended to be.

In addition to length of tenure, type of tenure may have important effects on the adoption of soil erosion control practices. The number of owner-operators increased from 59 to 77 between 1949 and 1957. Since there was little change in the number of part-owners during this time, the number of farms classified as tenant-operated dropped from 78 in 1949 to 55 in 1957. This classification of part-owners included only operators who owned or rented land, in addition to their headquarter farms, within the sample survey units. Classification of part-owners with regard to all land owned and operated yielded different results in table 12.

Farm size might be hypothesized as an important determinant of land use. Consequently, changes in farm size might be expected to result in changes in soil losses. The average size of headquarter farms in the sample in 1949, 1952 and 1957 and average soil losses are shown in table 21. Although the average size of sample farms increased only slightly between 1949 and 1957, there was a significant decrease in the soil loss means. While there may have been individual farms on which the change in acreage influenced a change in land use and hence a change in soil loss, this trend did not appear to have been typical for the entire sample.

TABLE 21. AVERAGE SIZE AND SOIL LOSSES ON HEADQUARTER FARMS IN A SAMPLE IN WESTERN IOWA, 1949, 1952 AND 1957.

Year	Farm size mean (acres)	Annual soil loss mean (tons per acre)
1949	169	21.1
1952	170	19.5
1957	172	14.1

Since the type of soil, degree of erosion, percent of slope and assumed slope length were the same for individual sample farms in 1949, 1952 and 1957, any reduction in soil loss had to result from either changes in management practices, rotations or special erosion-control practices. The trend in practice adoption for the most important special practices is shown in table 22.

TABLE 22. PROPORTION OF FARMS IN A SAMPLE IN WESTERN IOWA ON WHICH EROSION CONTROL PRACTICES WERE USED ON AT LEAST ONE FIELD, 1949, 1952 AND 1957.

Practice	Percent of farms where practice was used on at least one field		
	1949	1952	1957
Grass waterways	33	46	72
Contouring	51	65	62
Commercial fertilizer	42	60	47
Terracing	15	27	40

The trend toward adoption of most practices on at least one field in the sample farms has been upward since 1949. The largest percentage increases occurred in grass waterways and terracing. In the latter case, however, the practice had not been adopted even on one field on 60 percent of the farms. The proportion of farms using commercial fertilizer increased from 42 percent to 60 percent between 1949 and 1952. Between 1952 and 1957, however, it decreased from 60 to 47 percent. A large share of this decrease was explained by the lack of rainfall in the years just prior to 1957. Those years of low precipitation made commercial fertilizer appear to have been a less profitable practice in 1957 than in years with ample precipitation. The drouth years resulted in less favorable net worth positions of farm operators, thus reducing their ability to buy fertilizer relative to previous years. Also, in previous years, plant growth was limited, so that much of the previous year's application was carried over, thus eliminating the need for additional applications of fertilizer in 1957.

In addition to the adoption of special erosion-control practices, changes in rotations between 1949 and 1957 contributed to a reduction in soil losses. The percentage of land in sample farms by land use in 1949, 1952 and 1957 is shown in table 23. The decrease in proportion of land in row crops and corresponding increase in proportion of land in meadow contributed to the lower soil loss mean in 1957.

TABLE 23. PROPORTION OF LAND IN VARIOUS USES ON A SAMPLE OF FARMS IN WESTERN IOWA, 1949, 1952 AND 1957.

Land use	Percent of land		
	1949	1952	1957
Row crops	37.9	36.7	31.5
Small grains	22.7	23.4	20.7
Meadow	17.0	17.1	25.0
Permanent pasture	17.2	16.6	12.9
Other	5.2	6.2	9.9
Total	100.0	100.0	100.0

Corresponding to changes in special practices adopted on the sample farms are the changes in numbers of farm operators who objected to erosion-control practices in 1949 compared with 1957 (table 24). High forage rotations appeared to have been equally unpopular in both years. The larger percentage of farm operators objecting to terracing was explained by the greater amount of terracing recommended in 1957 than in 1949. Although the proportion of farm operators objecting to commercial fertilizer and grass waterways increased between 1949 and 1957, because of the larger recommendations of both, the proportions of those objecting to contouring decreased from 25.7 to 15.9 percent.

An important factor determining the adoption of erosion-control practices appeared to have been the financial ability of the owner to make the necessary cash outlays. The cost-price squeeze which farmers experienced during the 1950's probably was a factor limiting the number of erosion-control practices adopted. Evidence of this reduction in farm income is the parity ratio, which compares the index of prices received by farmers with the index of prices paid by them. The parity ratio stood at 100 for both 1949 and 1952, but fell to 82 in 1957 (31, p. 456). This decrease in the ratio of prices received by farmers to those paid by farmers illustrates one of the factors contributing to the increase in number of farms on which the need for immediate income was expressed as an obstacle.

TABLE 24. PROPORTION OF FARM OPERATORS IN A SAMPLE IN WESTERN IOWA WHO OBJECTED TO EROSION CONTROL PRACTICES, 1949 AND 1957.

Practice	Percent of farm operators who objected to practices	
	1949	1957
High forage rotations	71.5	71.7
High row-crop rotations	..[a]	51.4
Terracing	54.2	60.1
Commercial fertilizer	12.5	34.8
Grass waterways	9.7	21.0
Contouring	25.7	15.9

[a] In 1949 rotations were not divided when objections to practices were analyzed.

The relatively low precipitation in western Iowa during years prior to 1957 has been mentioned as an instrumental factor influencing erosion-control-practice adoption. Although the precipitation at Sioux City and Council Bluffs was higher in 1957 than in 1949 and 1952 (when the previous data were obtained from farm operators), the precipitation report for 1955 and 1956 showed them to be two of the lowest years in the 10-year period.[20] Since farmers tend to develop expectations which influence resource allocation based on previous experiences (16, pp. 465-499), the preceeding years of unfavorable weather conditions undoubtedly influenced not only erosion-control-practice adoption in 1957, but also farmers' reactions to the recommended practices.

STATISTICAL TESTS OF THE EFFECTS OF FARM CHARACTERISTICS ON SOIL LOSSES

The effects of the characteristics of the sample farms in 1957 on soil losses were investigated by means of multiple variable linear regression. The coefficient of multiple determination, R^2, for the regression equation was 0.639.[21] The F test for over-all sig-

[20] Shaw, Robert, Ames, Iowa. Data from precipitation records. (Private communication.) 1960.

[21] The following equation was computed for soil loss as a function of 29 characteristics:

$$Y = 8.00 + 5.40x_1^{**} - 1.32x_2 + 0.01x_3 - 0.08x_4 - 0.01x_5 + 0.49x_6 + 285.67x_7 - 0.70x_8 - 0.03x_9 - 0.64x_{10} - 3.13x_{11} + 5.50x_{12} - 2.65x_{13} - 0.04x_{14} + 0.55x_{15} + 2.41x_{16}^{**} + 3.36x_{17} + 0.20x_{18} + 1.32x_{19}^{*} - 0.92x_{20} - 2.80x_{21} + 0.18x_{22} - 0.67x_{23}^{*} - 1.88x_{24} - 1.20x_{25} - 4.73x_{26}^{**} + 0.00x_{27} - 1.26x_{28} + 0.52x_{29}$$

where

Y = soil loss,
x_1 = topographic index,
x_2 = type of tenure,
x_3 = number of years operator farmed the farm,
x_4 = age of operator,
x_5 = total number of acres farmed,
x_6 = type of farm,
x_7 = owner's obstacle of need for immediate income,
x_8 = operator's expectation of change in gross income 1 year after adoption of SCS Plan I,
x_9 = operator's expectation of change in gross income 5 years after adoption of SCS Plan I,

(footnote continued next page)

nificance of the regression, the mean square due to regression divided by the mean square deviations from regression, yielded $F = 364.13/55.33 = 6.58^{**}$. Consequently, the null hypothesis that the deviation explained by regression was equal to zero was rejected.

Further evaluation of the effects of the independent variables was accomplished by dropping groups of variables and recomputing the regression equation. The test to determine whether the difference in the variation explained by the reduced equation relative to the 29-variable model was due to chance was performed on the equations (1, p. 172). When only the five variables with significant sample regression coefficients in the 29-variable equation were included in another multiple variable linear regression equation, R^2 dropped from 0.639 to 0.512. The ratio, $F = 2{,}098.0/1{,}327.2 = 1.58$, indicated, however, that the difference in variation explained by the two equations was not significant at the 95-percent level of probability. But, when any of the independent variables, with sample regression coefficients that were significant between the 95- and 99-percent level of probability in the 29-variable model, were deleted from the 5-variable regression equation, the F ratios indicated that the difference in variation (explained by regression in the 29-variable model versus the 4-variable model) was significant at the 95-percent level of probability. Hence, the following characteristics were accepted as having a significant effect on soil losses: soil conservation district participation, topography, ability to borrow, days of off-farm work and operator's evaluation of the seriousness of the erosion problem.

Each of the independent variables with statistically significant sample regression coefficients had an effect on soil loss in the direction hypothesized. As soil conservation district participation increased from nonparticipation through initial cooperation to complete cooperation, soil loss tended to decrease. As the topographic index increased, soil loss increased also. The ability to borrow the necessary funds to install erosion-control practices was correlated with low soil loss. When the number of days of off-farm work increased, reducing somewhat the need for immediate income from the farm, soil loss tended to decrease. As the operator's estimation of the seriousness of the erosion problem increased (from a statement that it was no problem to somewhat of a problem, to a major problem) soil loss moved inversely.

The significant socio-economic characteristics of sample farms tended to substantiate the obstacles which were statistically significant. The relationships between soil loss and both the ability to borrow and the number of days off-farm work parallel the relationship between the obstacle of need for immediate income and soil loss. Similarly, the significance of the relationship between awareness of the erosion problem and soil loss substantiates the importance of the obstacle of failure to see the need for recommended practice—custom and inertia. Insofar as soil conservation district cooperators tend to be operators of large, well-financed farms (13), the characteristic of soil conservation district participation substantiates both the obstacles of need for immediate income and the obstacle of failure to see the need for recommended practice—custom and inertia.

In view of these findings, the second diagnostic hypothesis—if society's goal of 5 tons annual soil loss has not been gained, then socio-economic factors are responsible for preventing attainment of this norm—was accepted. Furthermore, in view of the importance of soil conservation district participation as an explanatory variable, the fourth diagnostic hypothesis—if present measures of action agencies have been successful, the rate of change in soil loss will be significant—was accepted also. Since soil conservation districts are charged with the responsibility for coordinating the efforts of action agencies relative to the erosion problem, it was considered a satisfactory criteria in testing this hypothesis.

Explanation of Major Obstacles

NEED FOR IMMEDIATE INCOME

Those 70 operators who indicated that need for immediate income prevented the adoption of one or more erosion-control practices were asked to give a further explanation of the obstacle. The answers given indicated that there were two basic reasons for this obstacle (table 25). One was the large out-of-pocket cash expense involved in adopting erosion-control practices. The second was the opportunity cost, or the income which operators felt they would have to forgo if the recommended erosion-control practices were adopted. Evidence of these basic causes for the obstacle are expressed in table 25.

TABLE 25. REASONS WHY NEED FOR IMMEDIATE INCOME WAS REPORTED TO BE AN OBSTACLE TO EROSION CONTROL ON 70 FARMS IN A SAMPLE IN WESTERN IOWA, 1957.

Reason	Number	Percent of 70 operators reporting obstacles
Cost of carrying out the erosion-control practices could be met, but equity in the farm would be reduced too low	43	61
Farm living expenses and debts need to be paid first	42	60
Income from a rented farm is not large enough to cover the cost of starting erosion-control practices	24	34
Operating expenses and outlays for purchasing more cattle would be too great in relation to the income from the farm	9	13
Cost of carrying out the practices is too high	6	9
Other reasons	3	4

(footnote 21 continued)

x_{10} = operator's expectation of change in gross income 10 years after adoption of SCS Plan I,
x_{11} = operator's expectation of change in gross income 1 year after adoption of SCS Plan II.
x_{12} = operator's expectation of change in gross income 5 years after adoption of SCS Plan II.
x_{13} = operator's expectation of change in gross income 10 years after adoption of SCS Plan II,
x_{14} = acres in acreage reserve of soil bank in 1957,
x_{15} = Agricultural Conservation Program participation,
x_{16} = soil conservation district participation,
x_{17} = work preference,
x_{18} = expectancy of tenure in 5 years,
x_{19} = operator's evaluation of seriousness of erosion problem,
x_{20} = number of units of livestock,
x_{21} = acres of meadow and permanent pasture in SCS Plan I per units of livestock on farm in 1957,
x_{22} = acres of meadow and permanent pasture in SCS Plan II per units of livestock on farm in 1957,
x_{23} = days of off-farm work,
x_{24} = need to borrow,
x_{25} = willingness to borrow,
x_{26} = ability to borrow,
x_{27} = price of the farm,
x_{28} = best investment possibility and
x_{29} = ability to invest compared with 5 years ago.

One method of alleviating the obstacle of need for immediate income was off-farm employment. Operators in the sample were classified by the number of days they spent doing off-farm work and the annual soil loss mean was calculated for each class. The 89 operators who did no off-farm work in 1957 had a soil loss mean which was 1 ton per acre higher than the average for the over-all sample. The average soil losses for groups of operators who worked off the farm or who had a family member who worked off the farm were consistently below the over-all sample soil loss mean of 14.1 tons per acre. Since average soil loss decreased with increasing number of days of off-farm work, off-farm jobs may be a potential remedial measure which might be expanded in western Iowa.

Table 26 indicates that the debt position of operators was not necessarily the primary factor in the obstacle of need for immediate income. Approximately the same proportion of operators with and without the obstacle had some short-term debts; however, the average short-term indebtedness per operator for those without the obstacle was considerably larger than those with it. Similarly, the proportion of operators with and without the obstacle who had some mortgage indebtedness was nearly the same. But the group without the obstacle had approximately $1,000 per operator more indebtedness than those with the obstacle.

TABLE 26. NUMBER OF OPERATORS WITH AND WITHOUT OBSTACLE OF NEED FOR INCOME WHO HAD SHORT-TERM MORTGAGE DEBTS AND THE AVERAGES OF THESE DEBTS FOR A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Class of operators	Short-term debt[a]		Mortgage debt[b]	
	Number[c]	Mean, dollars	Number[d]	Mean, dollars
Need for immediate income was an obstacle	34	1,878	25	9,810
Need for immediate income was not an obstacle	30	3,045	20	10,895

[a] Thirty-one operators with obstacle had no short-term debts and were not included; 37 operators without obstacle had no short-term debts and were not included.
[b] Forty-two operators with obstacle had no mortgage debts and were not included; 48 operators without obstacle had no mortgage debts and were not included.
[c] Six operators refused to disclose amount of short-term debt and were not included.
[d] Three operators refused to disclose amount of mortgage debt and were not included.

More important than the debt position of the operators in determining their obstacles were their expectations of returns relative to the costs of adopting erosion-control practices. Since it was determined early in the investigation that farm operators have very little knowledge of the costs of erosion-control practices, the information concerning their expectations of returns from these practices was obtained in terms of gross, rather than net, returns. In table 27, farm operators are grouped according to the percentage change in their gross returns anticipated 1, 5 and 10 years after the adoption of Plan I, the mechanical practices plan. Farm operators were not very optimistic in their expectations of increasing their gross returns as a result of the mechanical practices plan. Furthermore, there was evidence of a substantial lack of knowledge by farm operators relative to the expected change which erosion-control practices would make in their gross farm income.

Farm operators in the sample were more pessimistic about the effects on their gross farm income from Plan II than from Plan I (table 28). The number of operators expecting a decrease or no change in their gross income tended to decrease with time after practice adoption. If operators had considered the cost of the plan relative to their expected change in gross income, their economic evaluation of the plan would have been pessimistic, indeed.

TABLE 27. OPERATORS' ESTIMATES OF ADDITIONAL GROSS RETURNS TO FARMS FROM THE ADOPTION OF PLAN I, IN A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Percent group	Additional returns after		
	1 year (number)	5 years (number)	10 years (number)
Minus to 0 percent	71	32	28
1 to 33 percent	28	59	54
34 to 66 percent	4	10	16
67 percent and over	0	2	4
No estimate given	35	35	36
Total	138	138	138

TABLE 28. OPERATORS' ESTIMATES OF ADDITIONAL GROSS RETURNS TO FARMS FROM THE ADOPTION OF PLAN II, ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Percent group	Additional returns after		
	1 year (number)	5 years (number)	10 years (number)
Minus to 0 percent	82	66	63
1 to 33 percent	15	31	30
34 to 66 percent	3	3	6
67 percent and over	1	1	1
No estimate given	37	37	38
Total	138	138	138

Tables 27 and 28 show that the obstacle of need for immediate income is more likely to be encountered in high forage rotation plans than in mechanical practices plans. Operators objected to Plan II more than Plan I because of the income they expected to have to forego with the former. Primarily, the obstacle occurred in connection with Plan I because of cash costs of the practices.

As mentioned previously, farm operators in the sample had little knowledge of the expected costs of adopting erosion-control practices. Prior to the interview, the total cost of each mechanical practice plan was budgeted using cost coefficients obtained from SCS personnel in the area.[22] In the course of the interview, the total budgeted amount was reduced by the amount of the cost of the practices already adopted on the farm. Before that figure was presented to the farm operator, he was asked to estimate the costs of individual erosion-control practices in the mechanical practices plan. These results are tabulated in table 29. Of those who did estimate the cost of Plan I, three times as many overestimated the cost as underestimated it relative to the budgeted amounts. While farm operators' estimates of the effects of erosion-control plans on their gross income might be considered limited, their estimates of the costs were even more so.

Another indication of operators' expectations of returns to erosion-control practices relative to their costs was obtained. Operators were asked what they considered to be their first and second best investment alternatives. The most frequently mentioned investment preference, both as first and second choice, was

[22] The cost estimates excluded that part of the costs which would be covered by incentive payments from the Agricultural Conservation Program if the operator were a cooperator.

TABLE 29. A COMPARISON OF OPERATORS' ESTIMATES AND THE BUDGETED COST OF INSTALLING EROSION-CONTROL PRACTICES IN MECHANICAL PRACTICES PLANS FOR A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Class	Number	Percent
Operators' estimates above budgeted amounts	4	3
Operators' estimates below budgeted amounts	12	9
Operators' estimates the same as budgeted amounts	1	1
Estimate given for some practices	42	30
No estimate given for some practices	77	56
Other	2	1
Total	138	100

TABLE 30. FIRST AND SECOND INVESTMENT PREFERENCES EXPRESSED BY A SAMPLE OF FARM OPERATORS IN WESTERN IOWA, 1957.

Investment preference	First choice (number)	Second choice (number)
Livestock	79	47
Commercial fertilizer	21	36
Land	19	10
Machinery	5	8
Terraces	3	6
Buildings	2	8
Waterways	0	0
Other	9	23
Total	138	138

livestock (table 30). For both choices, commercial fertilizer and land followed in order of frequency mentioned. Investments in terraces and waterways were mentioned by relatively few operators as either a first or second choice. Consequently, operators did not favor erosion-control practices relative to other alternative investments.

After operators had been asked for their estimates of costs and returns of erosion-control practices, they were given the budgeted costs of Plan I and were asked about financing the plan. Of the 138 operators, 112 stated that it would be necessary for them to borrow funds to adopt Plan I. A large proportion of the operators interviewed said that they would not do so.

Of the 70 farm operators who were unwilling to borrow money to install Plan I, 26 said that uncertainty of income prevented them from doing so. Internal capital rationing was indicated by many of the operators' responses, particularly by the 16 who stated they preferred less indebtedness than would be possible if they were to adopt Plan I.

Of the 29 operators who stated that they could not borrow the necessary funds to install Plan I, nine said that equity in their farm was too small to borrow the necessary funds. Seven stated that their credit was limited by drouth, while five apparently had poor credit ratings. Only 5 of the 112 operators who said that it would be necessary to borrow funds stated that they could not do so because of the lack of availability of credit for the practices. Apparently, internal capital rationing is a more important component of the obstacle of need for immediate income than either external capital rationing by credit agencies or the lack of availability of credit agencies.

Another reason for the obstacle of need for immediate income was that many farm owners felt that the value of their farms would not be increased by investments in erosion-control practices. The operators were asked to estimate the price that their farms would sell for at the time of the interview. This information is presented in table 31 by soil loss classes and topographic groups. Both soil losses and topography were positively correlated with land prices. Topography was the more important influence of land prices, however, because it was also incorporated in the estimate of soil losses.

A multiple variable linear regression equation was computed to determine the relationship between changes in land prices and changes in soil loss. Forty-nine farms on which operators had estimated land prices in 1949 were included in the regression problem. The changes in land prices between 1949 and 1957 were regressed on changes in soil loss between 1949 and 1952, changes in soil loss between 1952 and 1957 and the 1957 soil loss. The resulting coefficient of multiple determination, R^2, was 0.02. Consequently, the null hypothesis that the independent variabl:s had no effect on the dependent variable was accept:d. Although the estimates of land prices were not sale prices, soil loss and changes in soil loss appeared to have had little or no effect on changes in land prices between 1949 and 1957.

FAILURE TO SEE THE NEED FOR EROSION-CONTROL PRACTICES

Operators' responses in connection with the failure to see the need for an erosion-control practice were recorded as specifically as possible. Later, these responses were grouped by erosion-control practices with a minimum of interpretation by the analyst. Consequently, evidence of the obstacle of failure to see the need is presented as it was expressed in con· nection with specific erosion-control practices.

The primary reasons for failure to see the need for contouring were that respondents felt that it was not needed and that the accompanying short rows made it undesirable.

Similar reasons were given for the obstacle in connection with terracing. Eleven operators said that terraces were too difficult to farm while eight explicity stated that terraces were not wanted. Operators who said that terraces were not wanted were distinguished from those who said that the practice was not needed, because the former saw the need for remedying the erosion problem but objected to terracing as a method of doing it. Those who failed to see the need for terracing were not aware of the need for action of that magnitude. The obstacle of failure

TABLE 31. SOIL LOSS IN TONS PER ACRE PER YEAR, TOPOGRAPHY CLASSES AND ESTIMATED MEAN VALUE PER ACRE OF FARMS IN A SAMPLE IN WESTERN IOWA, 1957.

Soil loss classes (tons/acres)	Topographic groups (index numbers): Less than 2		2 to 2.9		3 to 3.9		4 to 4.9		5 and over		Total[a]	
	No.	$/acre	No.	$/acre	No.	$/acre	No.	$/acre	No.	$/acre	No.	$/acre
0-4.9	14	276	8	253	3	192	1	150	3	117	29	240
5-9.9	16	255	12	202	5	120	5	134	.		38	205
10-19.9	8	228	12	188	10	150	3	101	1	200	34	179
20 and over	1	125	2	250	7	154	14	150	9	135	33	152
Total	39	254	34	212	25	150	23	140	13	136	134	193

[a] Information about land prices was not obtained on four farms.

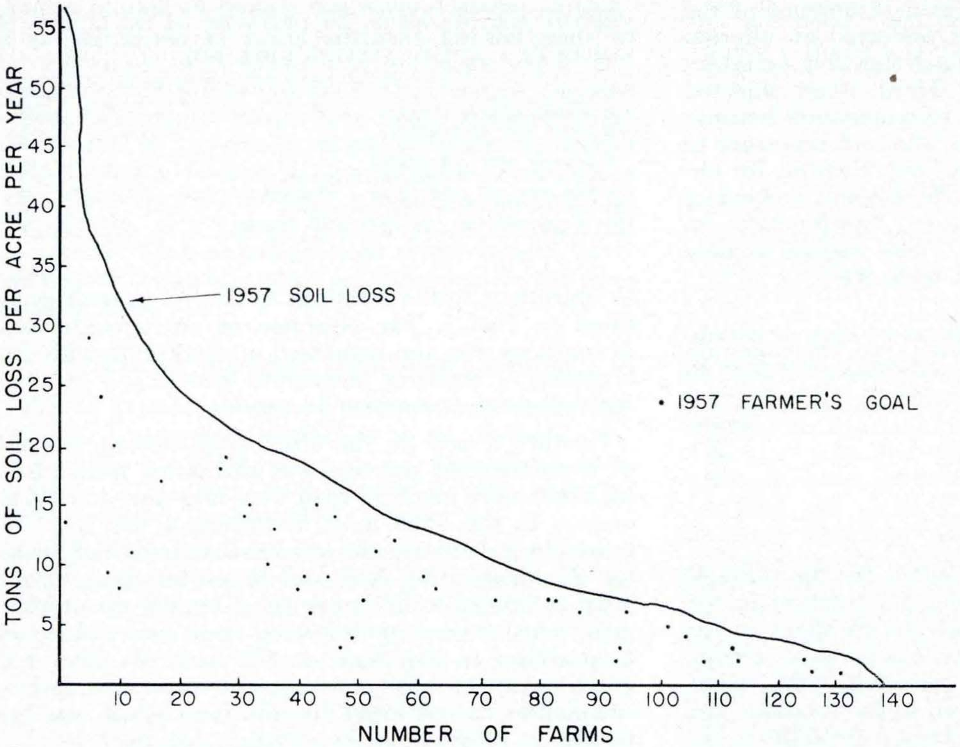

Fig. 5. Soil losses on 138 farms in western Iowa, arrayed according to decreasing soil loss in tons per acre and farmers' goals of soil losses when observed soil losses and farmers' goals differed, 1957.

to see the need for waterways was evidenced by the fact that eight operators explicitly stated that grass waterways were not needed.

More operators in the sample objected to commercial fertilizer than to grass waterways for reasons which were classed as failure to see the need for the practice. Nine of them said that fertilizer was not needed, three said that fertilizer failed to increase yields, two did not want to use fertilizer, and two thought that fertilizer did more harm than good.

Eleven operators explictly stated that they did not want contour fencing. Six operators said that the practice was not needed, and one said that it contributed to more erosion. These statements were considered evidence of the obstacle of failure to see the need for contouring fencing.

Evidence of the failure to see the need for erosion control also was gained by analyzing farm operators' goals of erosion control. In fig. 5, farms are arrayed in a ranking of 1957 soil losses. For operators who had erosion-control goals which differed from the practices already adopted, the level of soil erosion control which their goals would attain is located directly below their 1957 soil erosion rating. Seventeen percent of the farm operators whose 1957 soil losses were below 5 tons per acre had goals of reducing erosion still further. Of the farms with a 1957 erosion rating between the public goal of 5 tons per acre and the sample mean of 14.1 tons per acre, 24 percent had goals which would reduce soil erosion below the 1957 level. Fifty-six percent of the operators whose 1957 soil losses were between 14.1 and 23 tons per acre had goals which would reduce erosion on their farms. Only 38 percent of the operators with soil losses above 23 tons per acre in 1957, however, had goals of reducing their erosion below the 1957 level. For the most part, those operators who had relatively low 1957 soil losses also had goals which would reduce erosion proportionately more than would the goals of operators with soil losses above the over-all sample mean in 1957.

INFLUENCE OF CUSTOM AND INERTIA

Responses given by 33 farm operators which indicated that the influence of custom and inertia was an obstacle are presented in table 32. Although stated as different reasons, most operators with this obstacle resisted any change from their status quo with respect to erosion-control practices.

TABLE 32. REASONS WHY INFLUENCE OF CUSTOM APPEARED TO BE AN OBSTACLE TO EROSION CONTROL ON 33 FARMS IN WESTERN IOWA, 1957.

Reason	Number	Percent of 33 operators reporting obstacle
Operator preferred to continue farming "his" way	14	43
Operator preferred past methods of farming	9	27
Practices do not control erosion	7	21
Operator preferred another combination of practices	3	9
Total	33	100

AMOUNT OR KIND OF RECOMMENDED PRACTICES

Ninety operators in the sample stated that they would not adopt as much or the specific kind of erosion-control practice recommended in at least one of the SCS plans. There were several explanations of this obstacle. First, some operators objected to the practices because they did not have a goal of reducing erosion to the level called for in either farm plan.

Second, some objected to the kind or amount of the recommendations because they preferred an alternative combination of practices which they felt would reduce erosion to the public goal. Third, others objected to the amount of the practices recommended because they believed that the practices were not necessary to reduce erosion to the 5-ton loss limit. Reasons for objecting to practices because of the amount or kind of the recommendation were classed by practices to which the obstacle was raised. These reasons as they relate to terracing are listed in table 33.

TABLE 33. REASONS GIVEN FOR AMOUNT OR KIND OF RECOMMENDED PRACTICE BEING AN OBSTACLE TO THE ADOPTION OF TERRACING BY OPERATORS OF A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Reason	Number
Not as many terraces wanted	22
Not as many terraces needed	13
Terraces were too difficult to farm	2
Terraces failed to control erosion	1
Other	1

In table 34, evidence is presented for the obstacle of amount or kind of recommended rotation in the mechanical practices plan. Since the rotations in the maximum mechanical practices plans were recommended in conjunction with terracing, some intermediate plan calling for less corn in the rotations and also fewer terraces might have been acceptable to the 20 operators who disliked the rotations because they called for too much corn. Many of the 17 operators who objected to corn several years in succession stated that they did not believe that 2 years of a row crop in succession was a good farming practice.

TABLE 34. REASONS GIVEN FOR AMOUNT OR KIND OF RECOMMENDED ROTATION BEING AN OBSTACLE TO THE ADOPTION OF MAXIMUM MECHANICAL PRACTICES PLANS BY OPERATORS OF A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Reason	Number
Too much corn in rotations	20
Rotations with corn several years in succession were not wanted	17
Not enough corn in rotations	9
Rotations did not fit field characteristics	7
One rotation for whole farm was wanted	3
Impossible to establish meadow in the rotation	3

One rotation to which this objection was voiced was CCOMM. Farm planners in this area said that they recommended that rotation in preference to a CO_cCOM rotation because the former was slightly less erosive, and 2 years of meadow in a 5-year rotation was more profitable. The latter rotation, however, might have been preferable to some operators for several reasons. The cash cost of the latter rotation probably was less than that of the former because of the nitrogen furnished by the crop of sweetclover. Most importantly, custom favors the rotation which does not contain successive corn crops. At best, the difference in net returns for both rotations is probably small and not sufficient to overcome customary rotations for some operators.

Evidence of the obstacle of the amount or kind of recommended practice in connection with the high forage rotations is presented in table 35. The largest class of reasons for the obstacle was the lack of enough corn in recommended rotations. Both too much corn and corn several years in succession were stated as objections to the rotations in Plan II as well as to those in Plan I. The objection of not enough corn in rotations was also expressed in connection with the obstacles of need for immediate income and insufficient roughage-consuming livestock.

TABLE 35. REASONS GIVEN FOR AMOUNT OR KIND OF RECOMMENDED PRACTICE BEING AN OBSTACLE TO THE ADOPTION OF HIGH FORAGE ROTATION PLANS BY OPERATORS OF A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Reason	Number
Not enough corn in rotations	23
Too much corn in rotations	4
Rotations with corn several years in succession were not wanted	4
Rotations did not fit field characteristics	3
Rotation was not practical or economical	2
One rotation for whole farm was wanted	1
High forage rotations failed to control erosion	1

Another reason for the obstacle of amount or kind of recommended practice was that some farm plans included more practices than were necessary to reduce erosion to the 5-ton limit. Evidence of this was obtained by calculating the soil losses in both SCS plans for 27 farms. The 1957 soil losses for these farms were estimated to be below the 5-ton-per-acre public goal. Since several operators on these farms objected to practices in the plans on the basis of either too much or an unsatisfactory type of recommendation, calculation of soil losses for the farm plans was expected to provide insight into the obstacle.

A number of alternative assumptions were used in calculating the soil losses. First, the topographic index utilized in calculating the 1957 soil losses was used with the erosion factors for the recommended rotations and special practices. Initially, an average factor was used for the management variable. This calculation resulted in an estimate of an average soil loss of 2.81 tons per acre for mechanical practices plans recommended for the 27 farms. The average soil loss estimated for Plan II for this group was 4.5 tons per acre.

Since the plans called for practices which constitute good soil management, the soil loss estimates were recalculated using an erosion factor for good, rather than average, management. These calculations resulted in estimates of average soil losses of 1.97 and 3.15 tons per acre for Plan I and Plan II, respectively.

The topographic index used for calculating the 1957 soil losses included a factor for an assumed slope length of 200 feet. Recent data obtained in the national inventory of soil and water conservation needs by the United States Department of Agriculture indicated, however, that average slope lengths of 250 and 300 feet for Ida and Monona soils, respectively, were more realistic estimates for the area.[23] Use of the assumption of a 300-foot average slope length for all soils on the 27 farms, along with the assumption of good management, resulted in an estimate of the average soil loss of 2.32 tons per acre for Plan I and 3.70 tons for Plan II.

The consequence of farm plans including more practices than necessary to reach the 5-ton goal was analyzed by considering possible alternative practices which would have met the 5-ton requirement. On the

[23] Tyler, *op. cit.*

average, contouring could have been substituted for part or all of the terracing recommended in Part I for the subsample of 27 farms, and soil losses would not have exceeded 5 tons per acre. The average soil loss for the subsample would have been increased from 3.70 to 4.92 by moving from a COMMMM to a CO-MMM rotation in Plan II, for example. Since rotations other than COMMMM were recommended in Plan II, this was just an illustration of the type of change in the recommendations which would have resulted in farm plans with soil losses nearer the permissible level.

INSUFFICIENT ROUGHAGE-CONSUMING LIVESTOCK

The 51 farm operators who stated that insufficient roughage-consuming livestock was an obstacle preventing the adoption of one or more erosion-control practices were asked their reasons for the obstacle. Their responses are recorded in table 36.

Insight was gained into reasons why insufficient roughage-consuming livestock might have been an obstacle on sample farms by asking operators which enterprises they most preferred and which they least preferred. In table 37 it is seen that a combination of hog and cattle feeding was the most preferred and one of the least disliked enterprises. Cattle feeding and hogs, as separate enterprises, were preferred by 30 and 20 operators, respectively. Insofar as cattle-feeding enterprises were designed to utilize large amounts of roughage, preference for the practice tended to facilitate erosion control. On the contrary, when a large proportion of grain was included in the ration, the preference for cattle feeding had the same effect as the preference for hogs – it tended to increase the production of erosive row crops.

One possible reason for insufficient roughage-consuming livestock being an obstacle might have been

TABLE 36. REASONS INSUFFICIENT ROUGHAGE-CONSUMING LIVESTOCK WAS REPORTED TO BE A MAJOR OBSTACLE TO EROSION CONTROL ON 51 FARMS IN WESTERN IOWA, 1957.

Reason	Number	Percent of 51 operators reporting obstacle
Kind of livestock needed was not desired	22	43
Kind of livestock needed was too risky	18	35
Prices of livestock were too high to buy	15	29
Money was not available to buy more livestock	12	24
Necessary amount of livestock would reduce farm income too much	9	18
The change in livestock enterprises would necessitate too much additional operating expense	7	14
Other reasons	8	16

TABLE 37. WORK PREFERENCE EXPRESSED BY A SAMPLE OF FARMERS IN WESTERN IOWA, 1957.

Enterprise	First preference (number)	Last preference (number)
Hog and cattle feeding	43	1
Cattle feeding	30	3
Hogs	20	10
Beef cows	14	1
Dairy cows	9	23
No preference	6	45
Field crops	5	12
Sheep	4	15
Poultry	0	20
Dairy and poultry	0	3
Other	7	5
Total	138	138

TABLE 38. NUMBER OF FARM OPERATORS WHO INDICATED THAT INSUFFICIENT ROUGHAGE-CONSUMING LIVESTOCK WAS AND WAS NOT AN OBSTACLE AND RATIOS OF ACRES OF PASTURE AND MEADOW IN SCS PLANS TO ANIMAL UNITS ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

	Number	Average acres pasture and meadow in Plan I per animal unit	Average acres pasture and meadow in Plan II per animal unit
Insufficient roughage-consuming livestock was an obstacle	51	7.6	10.5
Insufficient roughage-consuming livestock was not an obstacle	87	8.2	12.6
Total	138	7.9	11.8

the lack of enough livestock to use the forage recommended in the erosion-control plans. Information concerning this reason is presented in table 38 by groups of farmers with and without the obstacle. There was relatively little difference in the ratios of acres of roughage per animal unit for the two plans for operators with and without the obstacle. More important than the difference in these ratios was the large average ratio for the entire sample. The 7.9 acres of roughage per animal unit in Plan I was significantly more than the 2-acre-per-animal-unit requirement estimated by SCS personnel in the area. The difference between the latter required acreage per animal unit and that recommended in Plan II is even greater than in Plan I. Consequently, a substantial number of roughage-consuming livestock would need to have been obtained by farm operators if the roughage produced in the two erosion-control plans were utilized.

RENTAL ARRANGEMENT AND LACK OF LANDOWNER'S COOPERATION

The 25 operators in the sample who stated that their rental arrangement and lack of landowner's cooperation was an obstacle were asked for an additional explanation of the problem (table 39).

Insights were gained into the obstacles of rental arrangement and short tenure by asking operators what the subjective probability was that they would be on the farm 1 year and 5 years after the interview. Those operators who said that there was less than a 100-percent subjective probability of their being on

TABLE 39. REASONS RENTAL ARRANGEMENT AND LACK OF LANDOWNER'S COOPERATION WAS REPORTED TO BE AN OBSTACLE TO EROSION CONTROL ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Reason	Number	Percent of 25 operators reporting obstacle
Landlord would object to the amount of corn he would receive under a crop-share lease	7	28
Landlord did not make other type investments in the farm	4	16
Rental arrangement did not provide for long enough tenure	4	16
Landlord objected to soil erosion practices in any form	3	12
Landlord probably would not permit the use of some of the practices but he had not been asked	3	12
Too much cash rent would have to be paid for hay and pasture under the crop-share lease	3	12
Livestock lease would be needed but such leases were not desired by operator or owner	2	8
Landlord would not agree to the practices under the existing lease	2	8

the farm 1 year after 1957 had an average soil loss of 1.8 tons per acre greater than the over-all soil loss mean. Similarly, those with that subjective probability rating for 5 years after 1957 also had a soil loss mean above the over-all mean. For both time periods, operators with 100-percent subjective probability of being on the farm had soil loss means below the over-all mean.

SMALL SIZE OF FARM

Since the obstacle of small size of farm was one of the most frequently mentioned in 1949, additional reasons for the obstacle were obtained in 1957. The lack of availability of additional land was cited as the reason for the obstacle.

Failure Elements Which Caused Soil Losses Greater Than the Program Goal From 1949-57

Use of the comparative statics method of analysis had the advantage of providing insights into changes within a problem area between points in time. The use of the same sample and similar methodology in analyzing the data facilitated the analysis of the effects of changes in failure elements over time.

RELATIONSHIPS BETWEEN CHANGES IN OBSTACLES AND CHANGES IN SOIL LOSSES

The effects of changes in five obstacles which were important in 1949 were analyzed for their effect in changing soil loss. In table 40, these five obstacles are listed and farms classified within each according to the occurrence of the obstacle. For each obstacle, farms are classified in the following groups: (1) the obstacle was not present from 1949 through 1957, (2) the obstacle was present in 1949, 1952 and in 1957, (3) the obstacle was present in either, or both, 1949 and 1952 but had been overcome by 1957, and (4) the obstacle was not present in both 1949 and 1952 but had become an obstacle by 1957.

TABLE 40. SOIL LOSSES BY CHANGES IN MAJOR OBSTACLES BETWEEN 1949, 1952 AND 1957 ON A SAMPLE OF FARMS IN WESTERN IOWA.[a]

Obstacle	Number	Annual soil loss mean (tons per acre)
Short expectancy of tenure		
Never was an obstacle	95	13.2
Was an obstacle but had been overcome by 1957	30	16.3
Was not an obstacle in both 1949 and 1952 but had become one by 1957	11	16.5
Was and still is an obstacle	1	18.1
Total	137	14.2
Rental arrangement and lack of landowner's cooperation		
Never was an obstacle	83	12.4
Was an obstacle but had been overcome by 1957	30	16.4
Was not an obstacle in both 1949 and 1952 but had become one by 1957	15	15.9
Was and still is an obstacle	9	20.9
Total	137	14.2
Amount or kind of livestock		
Never was an obstacle	46	9.8
Was an obstacle but had been overcome by 1957	40	14.4
Was not an obstacle in both 1949 and 1952 but had become one by 1957	40	17.5
Was and still is an obstacle	11	19.8
Total	137	14.2
Need for immediate income		
Never was an obstacle	51	10.2
Was an obstacle but had been overcome by 1957	17	12.5
Was not an obstacle in both 1949 and 1952 but had become one by 1957	59	16.7
Was and still is an obstacle	10	22.4
Total	137	14.2
Small size farm		
Never was an obstacle	83	13.2
Was an obstacle but had been overcome by 1957	44	15.9
Was not an obstacle in both 1949 and 1952 but had become one by 1957	5	13.4
Was and still is an obstacle	5	16.3
Total	137	14.2

[a] Information was not available for one sample farm in 1952.

The most important finding presented in table 40 is the persistent tendency for the soil loss mean on farms where each of the five major obstacles had never been present to be lower than the over-all sample mean. Also, all soil loss means exceeded the sample mean where the obstacles have been present constantly since 1949. The soil loss means for farms classified as having obstacles which changed between 1949 and 1957 were less than the soil loss means for farms which had never had the obstacle and greater than those which had had the obstacle during the entire period. In some cases the alleviation of one obstacle did not result in lower soil losses, nor did the soil losses always increase where the obstacle had not been present until 1957. On all farms, however, the presence or absence of one single obstacle in any one year did not eliminate the possibility of one or more additional obstacles being present. Consequently, examination of each obstacle-change class individually does not explain the entire effect of changes in obstacles preventing the adoption of soil erosion control practices.

F tests were run on farms within the change classifications for each obstacle to determine whether a significant amount of variation in soil loss could be explained by changes in the obstacles. The tests were run using both the 1957 soil loss and changes in soil loss between 1949 and 1957 as dependent variables.

Table 41 contains the results of the analysis of variance tests to determine whether the ratio of among obstacle change group mean square soil losses to within obstacle change group mean square soil losses was significant at the 95-percent level of probability. When 1957 soil losses were used as the dependent variable, the null hypothesis—that the variation explained by the obstacle change groups was not significantly greater than zero—was rejected for both the obstacles of need for immediate income and insufficient roughage-consuming livestock. The variation explained by changes in the obstacle of rental arrangement and lack of landowner's cooperation was nearly significant at the 95-percent level of probability.

TABLE 41. RESULTS OF STASTISTICAL TESTS OF THE RELATIONSHIP OF CHANGES IN OBSTACLES AND CHANGES IN SOIL LOSS ON A SAMPLE OF FARMS IN WESTERN IOWA, 1949-57.

Obstacle	F ratio of among mean square to within mean square for effects of changes in obstacles on 1957 soil loss	F ratio of among mean square to within mean square for effects of changes in obstacles on changes in soil loss, 1949-57
Need for immediate income	5.72**	1.29
Insufficient roughage-consuming livestock	5.03**	3.42*
Rental arrangement and lack of landowner's cooperation	2.46	0.21
Short expectancy of tenure	0.83	1.93
Small size of farm	0.65	1.04

Nevertheless, neither the changes in soil loss for that obstacle nor the changes for the obstacles of short expectancy of tenure and small size of farm were accepted as being statistically significant.

Since the classification of farms into change groups considered changes in obstacles since 1949, the effects of the changes were expected to have been related to changes in soil losses between 1949 and 1957 as well as the 1957 soil losses. The results of the analysis of variance tests, where changes in soil loss between 1949 and 1957 were used as the dependent variable, are presented in table 41. Changes in the obstacle of insufficient roughage-consuming livestock were the only changes in obstacles which resulted in changes in soil loss which were statistically significant. Even these results must be discounted, however, because soil loss had decreased, on the average, more on farms where the obstacle had been present continuously than in any other group. Consequently, the F tests for the effects of changes in obstacles on changes in soil loss indicated that the variation might have been due to chance at the 95-percent level of probability.

Since changes in individual obstacles might be expected to be interrelated with changes in other obstacles, a statistical procedure which would allow simultaneous consideration of changes within each obstacle for all obstacles appeared to be more applicable than analysis of variance as a statistical test. Two multiple regression equations were calculated with changes in soil losses as a function of changes in the five major obstacles. By using changes in obstacles as independent variables, however, it was necessary to assign a weight to each change group. The coefficients of multiple determination, using selected weights, were 0.03 and 0.04. The variation explained by regressing the changes in soil loss on changes in obstacles with these procedures was not significant at the 95-percent level of probability. This indicated that either no relationship existed or that a satisfactory weighting of obstacle change groups had not been developed. Other methods of regressing changes in soil loss on changes in obstacles failed to detect any significant relationship between the change groups. These results suggested that alleviation of one obstacle might have resulted in somewhat lower soil losses, but additional obstacles might have been encountered before soil losses decreased significantly.

As a result of these analyses, the third diagnostic hypothesis—if any of the observed obstacles are significantly different from those discovered by previous inquiries, then the rate of soil loss will have increased or decreased significantly depending upon the changes in obstacles—was not accepted. Since the evidence obtained in the analysis of variance of the effects of change groups on the 1957 soil loss might have included other factors contributing to variation in soil losses besides changes in obstacles, that series of tests was not satisfactory for accepting the hypothesis. Analysis of the effects of changes in obstacles on changes in soil losses needs further study using more data and other methods of analysis.

TABLE 42. CHANGES IN MAJOR OBSTACLES BETWEEN 1949, 1952 AND 1957, AND 1957 SOIL LOSSES ON FARMS WHERE SOIL LOSS INCREASED MORE THAN 5 TONS PER ACRE BETWEEN 1949 AND 1957 IN A SAMPLE IN WESTERN IOWA.

Obstacle	Number	Annual soil loss mean (tons per acre)
Need for immediate income		
Never was an obstacle	7	23.0
Was an obstacle but had been overcome by 1957	1	26.0
Was not an obstacle in both 1949 and 1952 but had become one in 1957	7	34.0
Was and remained an obstacle in 1957	3	33.6
Total	18	29.2
Amount or kind of livestock		
Never was an obstacle	7	23.0
Was an obstacle but had been overcome by 1957	2	45.2
Was not an obstacle in both 1949 and 1952 but had become one in 1957	8	26.8
Was and remained an obstacle in 1957	1	60.2
Total	18	29.2
Rental arrangement and lack of landowner's cooperation		
Never was an obstacle	1	13.8
Was an obstacle but had been overcome by 1957	3	41.0
Was not an obstacle in both 1949 and 1952 but had become one in 1957	3	22.8
Was and remained an obstacle in 1957	1	53.4
Total[a]	8	32.3
Short expectancy of tenure		
Never was an obstacle	14	26.6
Was an obstacle but had been overcome by 1957	2	39.7
Was not an obstacle in both 1949 and 1952 but had become one in 1957	2	36.8
Was and remained an obstacle in 1957	0	0
Total	18	29.2
Small size of farm		
Never was an obstacle	9	28.3
Was an obstacle but had been overcome by 1957	7	31.8
Was not an obstacle in both 1949 and 1952 but had become one in 1957	1	22.5
Was and remained an obstacle in 1957	1	26.0
Total	18	29.2

[a] Ten owner-operated farms were not included because the obstacle was not applicable.

CHANGES ON FARMS WHERE SOIL LOSSES INCREASED MORE THAN 5 TONS PER ACRE PER YEAR, 1949-57

Another method of analyzing the relationship between changes in soil losses and changes in obstacles was to examine the number of farms and soil losses on them where soil loss increased more than 5 tons per acre between 1949 and 1957. The results of this tabulation for 18 farms in the sample are presented in table 42. Soil losses on these farms averaged 29.2 tons per acre in 1957. Although the number of observations was relatively small when the farms were classified into obstacle-change groups, there did appear to be changes in some obstacles which influenced the 1957 soil loss. On the seven farms where the obstacle of need for immediate income had never been present, soil losses averaged 6.2 tons per acre less than the average for the entire group. Likewise, both the development of the obstacle in 1957 and the persistence of the obstacle for the entire period were related to average soil losses above the group soil loss mean.

Also, table 42 shows that the absence of each obstacle in 1949 through 1957 was associated with soil loss below the group mean. Similarly, the persistence of three obstacles from 1949 through 1957 was related to soil loss above the group mean. In the latter case, however, the small number of observations in each class makes it doubtful that much importance could be attached to the results.

CHARACTERISTICS AND OBSTACLES ON FARMS WHERE SOIL LOSSES INCREASED MORE THAN 5 TONS PER ACRE, 1949-57

Another method of examining failure elements causing soil losses to be greater than the program goal consisted of comparing selected characteristics for farms with changes in soil losses between 1949 and 1957 with those characteristics of the entire sample. The characteristics studied were selected on the basis of the statistical tests which indicated significant relationships between some farm characteristics as well as some obstacles and soil losses.

Selected characteristics on 18 farms where soil loss increased more than 5 tons per acre were compared with those characteristics for all farms in the sample. These 18 farms had an average soil loss 15.1 tons per acre higher than the over-all soil loss mean. Part of this difference in soil loss was explained by the slightly higher topography rating on the group of farms where soil losses increased. On the 18 farms there were substantially fewer cooperators in the Soil Conservation District Program, and a smaller proportion of the operators recognized the problem to the extent that it was recognized by operators in the entire sample. A smaller percent of the operators worked off the farm, and a smaller proportion had the ability to borrow funds for erosion-control practices than in the entire sample. Operators of the high-soil-loss businesses farmed an average of 165 acres, compared with the sample mean of 214 acres. Similarly, there were substantially fewer animal units per farm where soil losses increased between 1949 and 1957.

OBSTACLES AND CHARACTERISTICS ON FARMS WHERE SOIL LOSSES CHANGED LESS THAN 5 TONS PER ACRE FROM 1949-57 AND WERE ABOVE THE SAMPLE MEAN IN 1957

Failure elements also were expected to be found on farms where soil losses were relatively high and did not decrease as rapidly as most farms in the sample. A comparison of selected characteristics and obstacles for all farms in the sample was made with 13 farms where soil losses changed less than 5 tons per acre between 1949 and 1957 but were above the sample soil loss mean in 1957. Some of the difference in soil loss means between the 13 farms and the entire sample was explained by the higher topographic rating per farm. Approximately the same percentage of operators cooperated in the Soil Conservation District Program in both groups. A larger proportion of the operators of farms where soil losses were high and unchanged classified erosion as a major problem on their farms than did operators in the entire sample. A smaller percent of the operators worked off the farm and had the ability to borrow funds for erosion-control practices in the group of 13 farms than in the over-all sample. Although there was little difference in acres operated per farmer between the two groups, there were substantially more animal units per farm on the average in the entire sample than on farms where the soil losses were high and had changed little. There appeared to have been little difference between the two groups on the basis of proportion of various types of tenure.

Success Elements Causing Soil Loss to be Reduced in 1957

The analysis of the relationship between socio-economic characteristics of the sample farms and soil loss by multiple-variable linear regression, discussed previously, provided insight into not only failure elements preventing the reduction of soil loss but also success elements causing soil loss to be reduced. The regression analyses considered factors related to low levels of erosion as well as high soil losses. Consequently, not only the lack of soil conservation district participation, inability to borrow, small amount of off-farm work and failure to recognize the seriousness of the erosion problem were important in explaining low soil loss but also favorable ratings for these characteristics were considered. Similarly, the lack of obstacles preventing the adoption of erosion-control practices was considered in explaining the variation in soil loss with obstacles. Further insights were gained into success elements by examining groups of farms which were thought to have been homogeneous with respect to these success elements.

CHARACTERISTICS OF FARMS WITHOUT OBSTACLES

There were 26 farms in the sample on which there were no effective obstacles preventing the adoption of erosion-control practices in 1957. Operators of these farms stated that there was no particular reason why practices in one of the plans should not be adopted on their farm.

Although there were no obstacles preventing the adoption of erosion control practices according to the operators, soil loss on these farms still exceeded the public goal by 5.8 tons per acre. Nine operators had reduced their erosion to 5 tons per acre, and several others in this group indicated that they planned to reduce erosion to that level. On some of the farms in this group, however, there probably were obstacles which were not detected in the interviewing procedure.

The soil loss mean for the group of farms without effective obstacles was below the over-all sample mean, and the average topographic rating per farm was slightly higher than that for the entire sample. Proportionately, there were more operators without effective obstacles participating in the Soil Conservation District Program than all operators in the sample. Also, more of the operators without effective obstacles to erosion control recognized the seriousness of the problem than did the operators of the entire sample. With respect to the remaining characteristics—off-farm employment, ability to borrow, size of farm and units of livestock and type of tenure—the 26 farms on which there were no effective obstacles closely paralleled the entire sample.

Although one of the SCS plans for their farms was acceptable to operators of these 26 farms, the need for immediate income and the lack of enough livestock were obstacles to adoption of some practices.

CHARACTERISTICS OF FARMS WITH SOIL LOSSES BELOW 5 TONS PER ACRE

Success elements were observed on farms where soil losses had been reduced to the public goal. Twenty-seven farm operators had reduced soil loss on their farms to less than 5 tons per acre in 1957. The low soil loss mean for these farms was explained partially by the low topography rating relative to the average for the entire sample. The proportion of these farms classed as complete cooperators in the Soil Conservation District Program was approximately twice as large as the average proportion for the entire sample. Although the farms with soil losses below 5 tons per acre were very similar to the entire sample with respect to operators' estimates of the seriousness of the problem and days of off-farm work, a larger percent of these operators said that they had the ability to borrow funds for erosion-control practices than the 138 operators in the sample. The ability of the operators with low soil losses to borrow reflected their large businesses with respect to acres operated and units of livestock, relative to the entire sample. A slightly larger proportion of these operators were owner-operators than was true for the entire sample, on the average.

None of the most important obstacles preventing erosion-control-practice adoption for the entire sample was expressed by as large a proportion of operators of low-soil-loss farms. The need for immediate income was the most frequently occurring major obstacle on the 27 farms on which soil loss was below 5 tons per acre.

CHARACTERISTICS OF FARMS WITH ROUGH TOPOGRAPHY AND RELATIVELY LOW SOIL LOSSES

Farms with relatively rough topography require more erosion-control practices to reduce erosion to a specified level than do those with less erosive physical conditions. Consequently, farms with relatively rough topography on which soil losses had been reduced substantially were expected to provide insight into methods of overcoming obstacles.

Operators' characteristics and obstacles for 20 farms with soil losses below the sample mean and with topographic ratings at least 0.5 above the over-all mean were compared with the entire sample. Soil losses on these farms averaged 8.6 tons per acre, and the average topographic rating per farm was 3.7, compared with 14.1 tons per acre and an index of 2.5 for all farms in the sample. Operators of farms with relatively rough topography and low soil losses tended to cooperate more with the Soil Conservation District Program, recognized the seriousness of the erosion problem and worked off the farm more than did average operators in the entire sample. Although the relatively rough, low-soil-loss farms tended to be more than 30 acres larger on the average than the entire sample of farms, there appeared to be little difference between the two groups with respect to ability of the operator to borrow funds for erosion-control practices, number of animal units per farm and type of tenure.

Insufficient roughage-consuming livestock was the only significant obstacle occurring proportionately more frequently on farms with relatively rougher topography and lower soil losses than on all farms in the entire sample. The obstacle of need for immediate income was found on 40 percent of the farms with rough topography and soil losses below the sample mean. None of the other important obstacles for the entire sample was as frequently mentioned on these 20 farms.

EXPLANATION OF FACTORS RESPONSIBLE FOR SOIL LOSSES ON TENANT-OPERATED FARMS

Earlier inquiries by Frey, Held and Timmons indicated that the lack of landowner's cooperation was an obstacle preventing the adoption of erosion-control practices on tenant-operated farms. Consequently, nonoperating landowners, owners of tenant-operated farms in the sample, were interviewed in 1957. These data provided the basis for analysis of characteristics and obstacles of nonoperating landowners. In reality, obstacles expressed simultaneously by tenants and nonoperating landowners functioned to prevent the adoption of erosion-control practices. For analytical purposes, however, operators' and nonoperating landowners' characteristics and obstacles were analyzed separately. The data for nonoperating landowners were studied to detect success and failure elements influencing the 1957 level of erosion control. Since complete information was not obtained from all nonoperating landowners prior to 1957, it was impossible to analyze the effects of intertemporal changes on soil loss.

Failure Elements on Tenant-Operated Farms Causing Soil Losses to be Greater Than the Program Goal in 1957

Analysis of failure elements on tenant-operated farms consisted of (1) statistical tests of the effects of nonoperating landowners' obstacles on soil losses, (2) statistical tests to determine the relationship between nonoperating landowners' characteristics and soil losses and (3) examination of obstacles and characteristics of nonoperating landowners by groups of farms homogeneous with respect to success or failure elements.

RESULTS OF TESTS OF HYPOTHESIZED OBSTACLES

Forty-nine nonoperating landowners with farms in the sample were interviewed using procedures and questions similar to those used in interviewing farm operators.[24] When presented with the same two erosion-control plans as had been presented to the operators of their farms, nonoperating landowners indicated that several obstacles prevented the adoption of the recommended practices.

Table 43 shows the number of owners who objected to each obstacle and the average annual soil loss for their farms. The largest group of owners with a similar obstacle objected to a recommended practice because of either the amount or kind of practice recommended. The 27 operators who objected to practices because of the obstacle of need for immediate income had an average soil loss of 16.6 tons per acre, slightly higher than the largest group. Statements made by 22 nonoperating landowners indicated failure to see the need for recommended practices. Also implicit in some landowners' statements was the

[24] Information was not obtained from seven nonoperating landowners either because of the age of the owner, the fact that the owner was living in the same dwelling with the operator or that the owner refused to answer the questions.

TABLE 43. NUMBER AND AVERAGE SOIL LOSS ON 49 FARMS WHERE THE NONOPERATING LANDOWNER'S REACTIONS WERE CLASSED AS OBSTACLES TO SOIL EROSION-CONTROL PRACTICES IN WESTERN IOWA, 1957.

Obstacle	Number	Annual soil loss mean (tons per acre)
Amount or kind of recommended practice	37	16.2
Need for immediate income	27	16.6
Failure to see the need for recommended practice	22	16.0
Insufficient roughage-consuming livestock	15	20.8
Rental arrangement and lack of tenant's cooperation	13	16.0
Custom and inertia	6	21.3
Lack of cooperation of neighboring farmers	6	26.1
Field and road layout	4	24.8
Small size of farm	3	11.8
Lack of adequate machinery and power	2	20.0
Lack of adequate buildings	2	10.5
Risk and uncertainty	2	9.2

obstacle of custom and inertia. Thirteen nonoperating landowners gave their approval of erosion-control practices but stated that their tenants prevented adoption of the practices. Some said that their tenants lacked enough roughage-consuming livestock to utilize the forage which would be produced in the recommended rotations.

In table 44, the obstacles indicated by owners of tenant-operated farms are presented by erosion-control practices.[25] Three practices—terracing, Plan I and Plan II—were objected to primarily because of the amount or kind of recommendation. The obstacle of need for immediate income was voiced in connection with commercial fertilizer and Plan II more than any other practice. There were indications of failure to see the need for terracing and commercial fertilizer more than other practices. The obstacle of rental arrangement and lack of tenant's cooperation occurred in connection with all recommended practices, but most frequently with Plan II, contouring and contour fencing. More nonoperating landowners objected to Plan II than any other practice on the basis of insufficient roughage-consuming livestock.

A comparison of practices found on farms owned by nonoperators and the number who objected to recommended practices is presented in table 45. Six practices, which constituted the basic components of the farm plans, were recommended on all tenant-operated farms. There were 25 farms on which commercial fertilizer was not being used. Grass waterways and contouring were the practices found most frequently on tenant-operated farms. Forty-three of the 49 nonoperating landowners objected to the rotations in Plan II, 33 owners objected to terracing, while 30 of the 49 owners interviewed objected to the rotations in Plan I.

Statistical tests were made to determine which of the observed obstacles and nonoperating owners' characteristics explained a significant amount of variation in soil losses. The tested hypothesis were that each obstacle and characteristic had an effect on soil losses which was not different from zero at the 95-percent level of probability. In light of experience gained in analyzing obstacles and characteristics of operators of the sample farms, multiple-variable linear regression was used in testing the hypotheses.

Initially, multiple-variable linear regression was used to analyze the relationship between all owners' obstacles and soil losses on tenant-operated farms. When soil loss was regressed on all obstacles as separate independent variables, the coefficient of multiple determination, R^2, was 0.469. The F ratio of soil loss variation explained by regression, and the residual variation was 1.94, which was not significant at the 95-percent level of probability. Although the sample regression coefficients for topography and the obstacle of need for immediate income were significant at the 95-percent level of probability, their importance was heavily discounted by the failure of the regression equation to explain a significant amount of variation in soil losses.

In addition, a multiple-variable linear regression equation[26] was computed for soil loss as a function of topography plus owners' obstacles, with the exception that obstacles of failure to see the need for recommended practices and custom and inertia were con-

[25] The sum of the number of landowners who gave obstacles to specific practices may exceed the total number of owners reporting each obstacle because an obstacle could have prevented the adoption of more than one practice.

[26] The function fitted by multiple-variable linear regression was:

$$Y = -5.99 + 8.11x_1 + 1.25x_2 + 0.78x_3 + 4.67x_4 - 9.95x_5 - 0.21x_6 + 7.37x_7 - 0.42x_8 + 7.89x_9 + 2.84x_{10} + 3.85x_{11} + 4.39x_{12}$$

where

x_1 = insufficient roughage-consuming livestock,
x_2 = rental arrangement and lack of tenant's cooperation,
x_3 = small size of farm,
x_4 = need for immediate income,
x_5 = lack of adequate machinery and power,
x_6 = field and road layout,
x_7 = risk and uncertainty,
x_8 = lack of adequate buildings,
x_9 = lack of cooperation of neighboring farmers,
x_{10} = amount or kind of recommended practice,
x_{11} = failure to see the need for recommended practices—custom and inertia and
x_{12} = topography index.

TABLE 44. NUMBER OF 49 NONOPERATING LANDOWNERS WHO REPORTED SPECIFIC OBSTACLES TO SPECIFIC EROSION-CONTROL PRACTICES IN A SAMPLE IN WESTERN IOWA, 1957.

Obstacle	Practice (number)							
	Contouring	Terracing	Waterways	Fertilizer	Structures	Contour fencing	Plan I	Plan II
Amount or kind of recommended practice	0	14	2	2	1	6	22	16
Need for immediate income	0	4	1	11	1	1	7	24
Failure to see the need for recommended practice	5	14	0	9	1	3	0	0
Rental arrangement and lack of tenant's cooperation	6	4	2	2	1	5	2	8
Insufficient roughage-consuming livestock	0	0	0	0	0	1	6	14
Custom and inertia	0	0	0	3	0	2	2	2
Lack of cooperation of neighboring farmers	0	1	6	0	0	0	0	0
Field and road layout	1	1	1	0	0	2	0	0
Small size of farm	0	0	0	0	0	1	2	1
Lack of adequate machinery and power	1	2	0	0	0	0	0	0
Risk and uncertainty	0	0	0	0	0	0	0	2
Lack of adequate buildings	0	0	0	0	0	0	0	2

TABLE 45. NUMBER OF OWNERS OF 49 TENANT-OPERATED FARMS WHO OBJECTED TO ADDITIONAL EROSION-CONTROL PRACTICES IN FARM PLANS AND THE NUMBER OF SAMPLE FARMS ON WHICH PRACTICES WERE RECOMMENDED AND INSTALLED IN WESTERN IOWA, 1957.

Practice	Situation on farms: Practice not used	Situation on farms: Some of practice used	Landowners who objected to practice in farm plans	Landowners on whose farm practice was recommended in farm plans
Contouring	17	32	10	49
Terracing	31	18	33	49
Waterways	13	36	11	49
Fertilizer	25	24	20	49
Rotation I	..	..	30	49
Rotation II	..	..	43	49

solidated into one obstacle. These obstacles were combined because of the high intercorrelation between them (indicated in the correlation matrix prior to computation of the first regression problem), the logical similarities between the obstacles and the necessity to preserve continuity of method of analysis. The use of these independent variables resulted in a coefficient of multiple determination, R^2, of 0.467. The mean square due to regression divided by the mean square deviations from regression resulted in an F ratio of 2.356, which was significant at the 95-percent level of probability. Consequently, the hypothesis that the regression equation did not significantly explain variations in soil losses was rejected.

The sample regression coefficients were tested with a "t" test to determine whether they were significant at the 95-percent level of probability. The topographic index was the only variable for which the null hypothesis—that the regression coefficient was not significant at the 95-percent level of probability—was rejected.

A further attempt was made to determine which nonoperating landowners' obstacles caused a significant amount of variation in soil losses. Independent variables were dropped from the original regression model. The difference in variation due regression in the abbreviated model versus the original model was tested to determine whether it was significantly greater than zero. The regression equation was recomputed a number of times with different combinations of variables. When the variables other than the one with a significant standard regression coefficient were dropped, the difference in variation explained by regression between the models was not statistically significant at the 95-percent level of probability. Then the procedure was repeated, dropping first, the obstacle of insufficient roughage-consuming livestock and second, the obstacle of need for immediate income. The results were negative. Consequently, the null hypotheses—that the variation in soil loss explained by obstacles could have been due to chance at the 95-percent level of probability—were not rejected. Although not statistically significant, the hypothesized obstacles of livestock and income appeared to have been important because of the frequency with which they were mentioned and the relatively high soil losses with which they were associated.

Additional information concerning factors preventing the reduction of erosion on tenant-operated farms was obtained by regressing characteristics of the non-operating landowners on soil loss.[27] The test for significance of the regression resulted in $F = 193.31/93.33 = 2.07^{*}$. Consequently, the null hypothesis – that the variation in soil loss explained by the regression equation was not significant at the 95-percent level of probability—was rejected. The null hypotheses that the sample regression coefficients for the following variables were not significant at the 95-percent level of probability were rejected: topographic index, chances of owning farm 1 year after date of interview, age of owner and ability of owner to borrow funds for erosion-control practices. It should be noted, however, that the sample regression coefficient for age of owner had a negative sign. This meant that low soil losses were associated with owners above 65 years of age. In view of the short planning horizon of many owners of tenant-operated farms in that age group, this finding was somewhat contrary to expectations. The signs of the sample regression coefficients for the remainder of significant variables were in the direction hypothesized.

Since the characteristic of Soil Conservation District Program participation was statistically significant in explaining variations in soil losses on all farms in the sample, the original regression model was expanded by adding that characteristic as a 24th variable.[28] The test to determine whether the variation in soil loss explained by the regression equation was statistically significant resulted in $F = 190.74/101.14 = 1.886$. Since this F ratio is not significantly greater than that expected due to chance at the 95-percent level of probabiliy, the null hypothesis – that the regression equation did not explain variations in soil losses – was accepted.

In view of the somewhat differing results of the

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[27] The initial regression equation was:

$$Y = 2.15 + 7.95x_1^{**} + 1.05x_2 - 0.00x_3 + 6.27x_4 + 0.00x_5 + 0.37x_6 + 0.08x_7 - 2.20x_8 + 0.04x_9 - 3.57_{10}^{**} + 4.62x_{11} + 11.53x_{12} - 6.22x_{13} + 10.00x_{14} - 17.84x_{15} - 1.63x_{16} - 6.48x_{17} - 9.61x_{18}^{**} + 5.76x_{19} - 10.65x_{20}^{*} - 0.24x_{21} + 4.45x_{22} + 5.13x_{23}$$

where

x_1 = topographic index,
x_2 = owner's recognition of seriousness of the erosion problem,
x_3 = acres in farm,
x_4 = crop-livestock share versus other leases,
x_5 = acres of additional land owned,
x_6 = chances of owning farm 5 years after date of interview,
x_7 = owner's estimate of price of farm,
x_8 = mortgage debt on farm,
x_9 = the percent of income owner received from the farm,
x_{10} = chances of owning farm 1 year after date of interview,
x_{11} = owner's expectation of change in gross income 1 year after adoption of Plan I,
x_{12} = owner's expectation of change in gross income 5 years after adoption of Plan I,
x_{13} = owner's expectation of change in gross income 10 years after adoption of Plan I,
x_{14} = owner's expectation of change in gross income 1 year after adoption of Plan II,
x_{15} = owner's expectation of change in gross income 5 years after adoption of Plan II,
x_{16} = owner's expectation of change in gross income 10 years after adoption of Plan II,
x_{17} = sex of owner,
x_{18} = age of owner,
x_{19} = need of owner to borrow funds for erosion control practices,
x_{20} = ability of owner to borrow funds for erosion control practices,
x_{21} = presence of operator's obstacle of rental arrangement and lack of landowner's cooperation,
x_{22} = presence of operator's obstacle of need for immediate income and
x_{23} = presence of operator's obstacle of failure to see the need for the recommended practices.

[28] The regression equation fitted for the expanded model was:

$$Y = -16.15 - 3.48x_1 - 0.05x_2 + 0.02x_3 - 7.99x_4 + 0.01x_5^{*} - 0.04x_6 - 0.04x_7 + 7.74x_8 - 0.05x_9 - 2.67x_{10}^{*} + 2.08x_{11} + 13.31x_{12} - 18.03x_{13} - 3.56x_{14} - 5.55x_{15} + 3.58x_{16} - 0.41x_{17} - 1.03x_{18} + 10.79x_{19}^{**} - 2.77x_{20} + 4.45x_{21} + 12.93x_{22}^{**} - 2.94x_{23} + 5.13x_{24}$$

where x_1 through x_{23} were defined as in the initial model and x_{24} was soil conservation district participation.

statistical tests for the 23- and 24-variable models, another regression model was constructed. This model[29] included the seven independent variables which had significant sample regression coefficients in one or another of the previous models.

The test to determine whether the variation in soil loss explained by regression was significantly greater than zero yielded $F = 3.20^{**}$. The hypothesis that the variation due regression was not significantly greater than zero was rejected. To test the hypotheses that the sample regression coefficients were not different from zero at the 95-percent level of probability, "t" tests were performed. The hypotheses were rejected for the independent variables: acres of additional land owned, chances of owning farm 1 year after date of interview, need of owner to borrow funds for erosion-control practices and presence of operator's obstacle of need for immediate income. Consequently, these variables were considered the most important characteristics on farms which determined soil losses through, or in addition to, the previously determined obstacles.

NEED FOR IMMEDIATE INCOME

Of the 49 nonoperating landlords interviewed, 27 stated that the need for immediate income prevented them from adopting one or more erosion-control practices. As with the reasons for the obstacle of need for immediate income voiced by farm operators, landowners' reasons primarily centered on the cash costs of installing the recommended practices and the opportunity costs if the practices were adopted.

The amount of mortgage indebtedness of nonoperating landowners was not highly correlated with the obstacle of need for immediate income. Less than one-third of the owners interviewed had any mortgage indebtedness, and the nine owners with debt stated that need for immediate income was not an obstacle.

The four nonoperating landowners with mortgages on their farms and with the obstacle of the need for immediate income had $2,700 less debt per owner, on the average, than did those with a mortgage but without the obstacle. Consequently, mortgage indebtedness appeared to be a relatively poor indicator of the obstacle of need for immediate income.

Landowners' expectations of returns from erosion-control practices appeared to be more important than their indebtedness in determining their acceptance of the recommended practices. Table 46 presents the landowners' estimates of changes in their gross returns from the adoption of Plan I. Nearly 50 percent of the owners said they had no idea of the effects of a mechanical practices plan on their farm income. This applied to all three time periods in question. Of those making estimates, most owners expected the adoption

TABLE 46. LANDOWNERS' ESTIMATES OF ADDITIONAL GROSS RETURNS FROM THE ADOPTION OF PLAN I ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Additional gross returns (percent group)	Additional returns after 1 year (number)	5 years (number)	10 years (number)
Minus to 0 percent	18	13	12
1 to 33 percent	9	12	12
34 to 66 percent	0	1	2
67 percent and over	0	1	1
No estimate given	20	20	20
Other	2	2	2
Total	49	49	49

of the plans to have a negative or a slightly positive effect on their gross income 1 or 5 years after adoption. When asked about gross income in 10 years, however, the number of owners who stated that they expected the plans to increase their gross income from 1 to 33 percent equalled the number who expected that the plans would have no or a negative effect. As with the operators of all farms in the sample, many owners interviewed were lacking information or were pessimistic about the effects of the mechanical practices plans on their farm income.

Nonoperating landowners also were asked to estimate the effects on their farm income of the mechanical practices plans 1, 5 and 10 years after adoption. The landowners expected Plan II to be less profitable than Plan I (table 47). After 1, 5 and 10 years, 28, 26 and 25 operators, respectively, said that they expected the adoption of Plan II to have a negative or no effect on their gross income. A relatively large proportion of landlords interviewed said that they had no estimate of the effect that a high rotation plan would have on their gross income. Consequently, nonoperating landowners were consistent in their pessimism and lack of knowledge about the expected effects of erosion-control plans. They were more doubtful about the profitability of high forage rotation plans than mechanical practices plans.

TABLE 47. LANDOWNERS' ESTIMATES OF ADDITIONAL GROSS RETURNS FROM THE ADOPTION OF PLAN II ON 49 FARMS IN A SAMPLE IN WESTERN IOWA, 1957.

Additional gross returns (percent group)	Additional returns after 1 year (number)	5 years (number)	10 years (number)
Minus to 0 percent	28	26	25
1 to 33 percent	4	6	7
34 to 66 percent	0	0	0
67 percent and over	0	0	0
No estimate given	15	15	15
Other	2	2	2
Total	49	49	49

Information about the expected effects of adoption of erosion-control plans on farm income was obtained for gross, rather than net, returns because few landlords had any estimate of the costs of practices. Sixty-eight percent of the nonoperating landowners interviewed gave no estimate of the expected costs of installing Plan I. Of those estimating the total cost of the practices, most owners underestimated the cost relative to the costs obtained by budgeting cost estimates obtained from SCS personnel.

Owners who depended largely on their farm for income were expected to have land with high soil losses. Conversely, owners with little dependence on farm income were expected to have land with low soil losses. Information about this relationship is pre-

[29] The regression equation calculated was:

$$Y = 5.10 - 0.97x_1 + 0.01x_2^{*} - 2.19x_3^{*} + 1.48x_4 + 8.27x_5^{*} + 0.22x_6 + 10.97x_7^{**}$$

where

x_1 = topographic index,
x_2 = acres of additional land owned,
x_3 = chances of owning farm 1 year after date of interview,
x_4 = age of owner,
x_5 = need of owner to borrow funds for erosion-control practices,
x_6 = ability of owner to borrow funds for erosion-control practices, and
x_7 = presence of operator's obstacle of need for immediate income.

TABLE 48. NUMBER OF OWNERS OF TENANT-OPERATED FARMS BY PERCENT OF INCOME DERIVED FROM FARM, AND SOIL LOSS IN TONS PER ACRE ON 49 FARMS IN A SAMPLE IN WESTERN IOWA, 1957.

Percent of income from farm	Number	Annual soil loss mean (tons per acre)
0-19.9	16	15.9
20-49.9	14	12.0
50 and over	17	18.2
Other	2	12.0
Total	49	15.4

sented in table 48. Although owners who depended on their farms for 50 percent or more of their income had an average soil loss of 18.2 tons per acre, those who depended on their farms for less than 20 percent of their income also had soil losses above the mean for all tenant-operated farms. While dependence on their farm for a large proportion of income may have caused relatively high soil losses on some owners' farms, the lack of dependence for income did not necessarily result in average soil losses below the over-all mean.

After having been told the budgeted cost to adopt the mechanical practices plan, owners were asked whether they would need to and be willing to borrow funds for that purpose. Of the 49 nonoperating landowners 24 said that they would have to borrow funds to establish the practices in Plan I. Half of those needing to borrow said that they would not be willing to borrow funds to install the mechanical practices plan.

The owners who were not willing to borrow the funds were asked for their reasons. Although their responses varied, the reason given most frequently was self-rationing of capital. These responses were not surprising in view of the fact that 27 of the 49 landlords were past 65 years of age.

Economic justification for adoption of erosion-control practices rests on two conditions from the individual firm viewpoint. Either it must be assumed that the returns from a practice will exceed its cost by increasing the productivity of other production inputs, or the increase in the price of the farm must exceed the cost of adopting the practice. In view of the relatively long time required before some erosion-control practices increase the productivity of other production inputs and the relatively short average length of ownership of farms in Iowa, effects of erosion on land values were thought to have been important in determining erosion-control-practice adoption. In table 49, the number and average value per acre of 46 tenant-operated farms are presented by topographic and soil loss groups. Land values tended to move inversely both with respect to topography and soil loss. As pointed out in connection with table 29, topography appeared to be the more important since it also entered into the estimate of soil loss.

DISLIKE FOR TYPE OR AMOUNT OF RECOMMENDED PRACTICE

The obstacle mentioned most frequently by nonoperating landowners was dislike for type or amount of a recommendation. Their reasons for this obstacle are presented by practices in table 50.

Many of the reasons for the owner's obstacle of dislike for the type or amount of recommendation were the same as those given by operators.

TABLE 50. REASONS GIVEN BY OWNERS OF 37 TENANT-OPERATED FARMS WHY DISLIKE FOR TYPE OR AMOUNT OF RECOMMENDATION WAS AN OBSTACLE TO EROSION CONTROL ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Reason	Practice		
	Terraces (number of farms)	Plan I (number of farms)	Plan II (number of farms)
Dislike for corn several years in succession	0	9	1
Not as much of practice wanted	8	0	0
Not enough corn	0	6	4
Failure to control erosion	0	0	5
Practice makes farming too difficult	4	0	2
Only one rotation is wanted	0	3	2
Not as much of practice needed	3	0	0
Other	1	4	2

FAILURE TO SEE THE NEED FOR A RECOMMENDED PRACTICE

One owners' obstacle which occurred frequently was failure to see the need for a recommended practice. Presence of this obstacle was detected in implicit rather than explicit statements. One evidence of the obstacle was owners' evaluation of the seriousness of the erosion problem (table 51). Soil losses were considerably higher on farms where nonoperating landowners said that erosion was a major problem than on farms where nonoperating landowners said that it was no problem. Further analysis of the data presented in table 51 indicated that owners interpreted the question used in getting the information in two ways. Some said that erosion was a major problem because losses were high, while others said that it was a major problem because of the difficulties which they had encountered in reducing erosion. On five of the tenant-operated farms, where the owners said that erosion was a major problem there was an average soil loss of 30 tons per acre. On the remaining eight

TABLE 51. IMPORTANCE OF THE EROSION-CONTROL PROBLEM EXPRESSED BY NON-OPERATING LANDOWNERS AND CORRESPONDING SOIL LOSS IN TONS PER ACRE FOR A SAMPLE OF TENANT-OPERATED FARMS IN WESTERN IOWA, 1957.

Seriousness of the problem	Number	Annual soil loss mean (tons per acre)
Major problem	13	16.7
Somewhat of a problem	17	14.7
Problem, needs no action	2	28.6
No problem	16	14.3
Other	1	3.7
Total	49	15.4

TABLE 49. NUMBER AND MEAN VALUE PER ACRE OF FARMS BY TOPOGRAPHIC GROUPS AND SOIL LOSS GROUPS FOR A SAMPLE OF 46 TENANT-OPERATED FARMS IN WESTERN IOWA, 1957.[a]

Soil loss	Topographic group (index number)									
	Less than 2		2 to 2.9		3 to 3.9		4 and over		Total	
(tons per acre)	No.	$/acre	No.	$/acre	No.	$/acre	No.	$/acre	No.	$/acre
0-9.9	6	257	4	206	4	165	5	180	19	207
10-19.9	6	256	6	186	5	163	1	100	18	198
20 and over			2	212	4	129	3	106	9	140
Total	12	256	12	197	13	153	9	147	46	190

[a] Information was not available for three farms. See earlier section "Soil Loss Estimates" for derivation of topographic groups.

farms where the owners classified erosion as a major problem, however, difficulty was experienced in holding soil losses at relatively low levels.

In many cases, nonoperating landowners stated that the recommended practices were either not needed or not wanted. They were particularly critical of terraces because of the difficulty of farming over them. They objected to commercial fertilizer because of its cash cost. Some landlords felt that it was more economical to rely on animal and green manure for the necessary fertilizer. Other owners stated that commercial fertilizer cemented the soil, killed earthworms and caused other destruction of the soil. A number of owners said that terracing wasted good soil, resulted in undesirable field boundaries or was foolish.

RENTAL ARRANGEMENTS AND LACK OF TENANT'S COOPERATION

Not only did some tenants say that their rental arrangement and lack of landowner's cooperation was an obstacle, but also some nonoperating landowners cited the same obstacle with respect to their tenants. Information concerning the types of leases found on all tenant-operated farms in the sample is presented in table 52. There was relatively little difference in average soil losses on tenant-operated farms with various kinds of leases. The two most frequently occurring types of leases, cash-crop share and crop-livestock share, were found on farms with average soil losses slightly above the group mean. Although farms with other types of leases had average soil losses which deviated substantially from the over-all group mean, few farmers had leases other than the most frequently occurring ones.

TABLE 52. AVERAGE SOIL LOSSES IN TONS PER ACRE ON 56 FARMS BY TYPE OF LEASE IN A SAMPLE IN WESTERN IOWA, 1957.

Type of lease	Number	Annual soil loss mean (tons per acre)
Cash-crop share	28	15.8
Crop-livestock share	18	15.8
Crop share	5	17.6
Cash	3	12.1
Other	2	12.9
Total	56	15.7

Insofar as crop-livestock share leases would result in more livestock on tenant-operated farms, they were expected to facilitate adoption of high-forage rotations. One landowner said that ineligibility to receive social security payments when a crop-livestock share was used prevented the use of that type of lease on his farm.

In addition to type of lease, another hypothesized reason for the rental arrangement having been an obstacle was the short expectancy of continued ownership of landlords. Consequently, nonoperating landowners were asked what the subjective probability was of their owning their sample farm 5 years after the date of interview. Most of the owners interviewed would not estimate the probability of their owning their farm in 1962. On four farms where the owner said that there was a 50 percent or less chance that he would own the farm in 5 years, the average soil loss was 27.4 tons per acre. On 11 farms where the owner stated that there was a greater than 50 percent subjective probability of owning his farm at that time, soil losses averaged 13.5 tons per acre.

In addition to the rental arrangement, another part of the obstacle mentioned by nonoperating landowners was the lack of tenant's cooperation. In some cases, owners said that they would not ask tenants to invest in the practices because the investment would be too large. In other cases, owners said that either their tenants refused to follow the recommended practices or that it was difficult to find tenants who would. Some owners indicated that they felt that the practices would not be profitable for either themselves or their tenants. Nonoperating landowners were in agreement that the tenant's cooperation was necessary if the recommended practices were to be adopted successfully.

SIMILARITIES BETWEEN FARM OPERATORS AND NONOPERATING LANDOWNERS

Because some obstacles resulted in higher soil loss on tenant-operated farms than on all farms in the sample, this facet of the problem was investigated by comparing characteristics and obstacles of nonoperating landowners (landlords) with those of the 138 farm operators in the sample.

CHARACTERISTICS OF 138 FARM OPERATORS AND NONOPERATING LANDOWNERS

Soil loss averaged 15.4 tons per acre on 49 tenant-operated farms, while the average for all farms in the sample was 14.1 tons per acre (table 53). Nonoperating landowners participated in the Soil Conservation District Program and had farms with topography similar to those characteristics on all farms in the sample. A smaller proportion of landlords appreciated the seriousness of the erosion problem than did operators. More nonoperating landowners were able to borrow funds for erosion-control practices, on the average, however, than were operators of the

TABLE 53. OPERATORS' CHARACTERISTICS AND OBSTACLES AND THOSE OF NONOPERATING LANDOWNERS IN A SAMPLE IN WESTERN IOWA, 1957.

Item	Units	Landowners' mean	Operators' mean
Farms	(number)	49	138
Soil loss per farm	(tons per acre)	15.4	14.1
Topographic rating per farm	(index number)	2.4	2.5
Soil Conservation District participation			
Complete cooperator	(percent)	31	33
Initial cooperator	(percent)	22	17
Noncooperator	(percent)	47	50
Estimate of seriousness of problem			
Major problem	(percent)	26	43
Somewhat of a problem	(percent)	41	34
No problem	(percent)	33	23
Ability to borrow funds for erosion-control practices	(percent)	89	70
Acres per farm	(acres)	175[a]	172
Animal units per farm	(animal units)	26.2[a]	33.2
Obstacles			
Need for immediate income	(percent)	55	51
Custom and failure to see need	(percent)	53	42
Rental arrangement and lack of landowner's cooperation	(percent)	27	51[b]
Insufficient roughage-consuming livestock	(percent)	31	37

[a] All tenant-operated farms were included.
[b] Only tenant-operators were used in computing the percentage.

sample farms. The two groups were similar with respect to the average size of farm measured in acres, but the units of livestock on tenant-operated farms were substantially below the over-all sample mean.

MAJOR OBSTACLES EXPRESSED BY FARM OPERATORS AND NONOPERATING LANDOWNERS

The need for immediate income was reported with slightly more frequency by nonoperating landowners, on the average, than by the 138 farm operators interviewed. Also, the obstacle of custom and inertia plus failure to see the need for recommended practices was found among a larger proportion of nonoperating landowners than operators. On the basis of percentage reporting, the obstacle of insufficient roughage-consuming livestock was more serious for operators than for nonoperating landowners. The largest difference in percent of operators versus percent of nonoperating landowners reporting an obstacle occurred in connection with rental arrangement and lack of landowner's and/or tenant's cooperation. Fifty-one percent of the tenant-operators listed it, while only 27 percent of the nonoperating landowners said that it was an obstacle.

OBSTACLES COMMON TO OWNERS AND OPERATORS OF TENANT-OPERATED FARMS

The statistical tests, discussed previously, indicated that there were some operators' and some nonoperating landowners' obstacles which had a significant effect on soil loss. On tenant-operated farms, however, the tests did not indicate whose obstacles were more important in preventing the reduction of erosion. On tenant-operated farms where an obstacle was agreed upon by both owner and operator, soil losses were expected to have been higher than when either the owner or operator alone experienced the obstacle. The evidence presented in table 54 does not support the hypothesis for all obstacles.

Further insight was gained into the relative importance of tenants' versus landlords' obstacles by regressing soil loss on topography, operators' obstacles and owners' obstacles on tenant-operated farms. To facilitate computation, only the most important obstacles, as indicated by their frequency and sample regression coefficients in the previous regression models, were used in the multiple variable linear regression.

When soil loss was regressed simultaneously on obstacles expressed by tenants and nonoperating landowners, a multiple coefficient of determination, R^2, of 0.691 was obtained.[30] The test for over-all significance of regression resulted in $F=223.0/77.6=2.87^{**}$. Consequently, the null hypothesis that the regression did not explain variations in soil loss was rejected. The variables with significant sample regression coefficients were tenants' obstacle of lack of adequate machinery, nonoperating landowners' obstacle of field and road layout, nonoperating landowners' obstacle of lack of cooperation of neighboring farmers and topographic index. Although not quite significant at the 95-percent level of probability, the tenants' obstacle of need for immediate income and their obstacle of field and road layout were important variables explaining soil loss.

SUCCESS ELEMENTS CAUSING SOIL LOSS TO BE REDUCED ON TENANT-OPERATED FARMS IN 1957

Several groups of tenant-operated farms where soil losses were low, relative to the group mean, were studied in an effort to diagnose success elements. Obstacles and characteristics, primarily of the owners of the farms, were analyzed. Results of the statistical tests were used in determining the important characteristics and obstacles considered.

CHARACTERISTICS AND OBSTACLES OF NONOPERATING LANDOWNERS WHO HAD NO EFFECTIVE OBSTACLES

Seven nonoperating landowners did not voice ob-

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[30] The regression equation was:

$$Y = -6.47 - 0.39x_1 + 0.54x_2 + 0.02x_3 - 0.15x_4 - 0.74x_5 + 0.22x_6 + 0.63x_7 + 0.10x_8 - 1.18x_9 - 0.48x_{10} + 1.04x_{11} + 0.26x_{12} + 0.46x_{13} + 0.64x_{14} + 0.39x_{15} + 1.22x_{16} + 0.08x_{17} + 0.37x_{18} + 0.51x_{19} + 0.07x_{20} + 0.42x_{21}$$

where

x_1 = tenants' obstacle of insufficient roughage-consuming livestock,
x_2 = landlords' obstacle of insufficient roughage-consuming livestock,
x_3 = tenants' obstacle of rental arrangement and lack of landowner's cooperation,
x_4 = landlords' obstacle of rental arrangement and lack of tenant's cooperation,
x_5 = tenant's obstacle of small size of farm,
x_6 = landlords' obstacle of small size of farm,
x_7 = tenants' obstacle of need for immediate income,
x_8 = landlords' obstacle of need for immediate income,
x_9 = tenants' obstacle of lack of adequate machinery and power,
x_{10} = landlords' obstacle of lack of adequate machinery and power,
x_{11} = tenants' obstacle of field and road layout,
x_{12} = landlords' obstacle of field and road layout,
x_{13} = tenants' obstacle of short expectancy of tenure,
x_{14} = tenants' obstacle of risk and uncertainty,
x_{15} = tenants' obstacle of lack of cooperation of neighboring farmers,
x_{16} = landlords' obstacle of lack of cooperation of neighboring farmers,
x_{17} = tenants' obstacle of amount and kind of recommended practice,
x_{18} = landlords' obstacle of amount and kind of recommended practice,
x_{19} = tenants' obstacle of failure to see the need for recommended practice—custom and inertia,
x_{20} = landlords' obstacle of failure to see the need for recommended practice—custom and inertia and
x_{21} = topographic index.

TABLE 54. NUMBER AND AVERAGE SOIL LOSS ON FARMS WHERE PRIMARY OBSTACLES WERE INDICATED BY OPERATORS ONLY, BY LANDOWNERS ONLY AND BY BOTH OPERATORS AND OWNERS OF TENANT-OPERATED FARMS IN A SAMPLE IN WESTERN IOWA, 1957.

Obstacle	Operator only		Landowner only		Both operator and landowner	
	Number	Annual soil loss mean (tons per acre)	Number	Annual soil loss mean (tons per acre)	Number	Annual soil loss mean (tons per acre)
Amount or kind of recommended practice	6	9.6	10	15.0	27	16.7
Need for immediate income	8	18.3	10	16.9	17	17.7
Rental arrangement and lack of landowner's and/or tenant's cooperation	15	18.9	7	23.5	6	8.9
Failure to see the need for recommended practice	5	22.4	13	17.4	9	13.9
Insufficient roughage-consuming livestock	11	12.9	6	18.0	9	22.6
Custom and inertia	7	20.6	1	18.6	5	21.8
Field and road layout	6	19.3	3	26.8	1	18.6

stacles to both SCS plans for their farm. Soil loss on these farms without effective obstacles averaged half as large, on the average, as on all tenant-operated farms. Although none of these farms was classed as a complete cooperator in its Soil Conservation District Program, nearly half of them had received some assistance through the program. A smaller proportion of these landlords were able to borrow funds for erosion-control practices than in the entire sample of nonoperating landowners. Not only were no effective obstacles present for owners of these farms, but also only a small percentage of their tenants had the obstacle of need for income. Nonoperating landowners without effective obstacles were not different from the entire sample of landlords with respect to topography, awareness of the problem or age of owner, on the average.

CHARACTERISTICS AND OBSTACLES ON TENANT-OPERATED FARMS WITH SOIL LOSSES BELOW 5 TONS PER ACRE

Six tenant-operated farms where the public goal had been achieved had a soil loss mean of 3.6 tons per acre. Most of the relatively low average soil loss was due to the lack of a severe erosion hazard on the farms. With respect to several other characteristics and obstacles, these farms were similar to the average of those owned by other landlords interviewed. The only ways in which they differed substantially were: older age of landlords, more cash-crop share leases and fewer tenants with the obstacle of need for income.

CHARACTERISTICS OF TENANT-OPERATED FARMS WITH RELATIVELY ROUGH TOPOGRAPHY AND LOW SOIL LOSSES

Success elements were expected to be found on tenant-operated farms with severe erosion hazards yet a low soil loss. There were nine tenant-operated farms where the topographic rating was above 3 and soil loss averaged 7.9 tons per acre. Although a smaller percentage of this group participated in the Soil Conservation District Program, a larger proportion of them recognized the seriousness of the problem than did all owners in the sample. The group differed from the entire group of landlords in that there was a larger proportion of crop-livestock share leases and fewer statements of the obstacle of need for immediate income by operators and owners.

POSSIBLE APPROACHES TO EROSION CONTROL

Progress toward controlling erosion rests upon research into its basic causes, education of the public concerning expected consequences of erosion and alternative methods of controlling it, and direct public assistance to landowners and operators. Research into the causes and consequences of erosion, as well as alternative control methods is a necessary foundation of the development of logical educational and other public assistance programs. Extension of the research findings through educational programs aids operators in making rational decisions with respect to land use. If society desires that this nation's resources be used in a way that is different from that which is economically justifiable for the individuals managing the resources, direct public programs must be devised to accomplish society's goals through public investments or control measures.

IMPLICATIONS OF OBSTACLES FOR PROGRAM GOALS

The findings of this analysis have implications for program goals for two reasons. First, the importance of the obstacle of need for immediate income, as evidenced by its persistance over time and its widespread presence—either expressed as an obstacle by operators and non-operating landowners or through farm characteristics—raises a question of the acceptability of the assumption of a soil loss goal of 5 tons per acre made at the outset of the inquiry. Second, relative weights must be placed on alternative methods of remedying obstacles responsible for the gap between the erosion situation and the program goal.

The 5-ton-per-acre-soil-loss goal is based on the assumption that sustained agricultural use of the Ida-Monona soil association area will be necessary for an indefinite period in the future. Re-examination of the goal is needed from both the public and the firm viewpoint. The growth of agricultural surpluses, in part a result of advances in technology, may raise serious questions from the public viewpoint about the magnitude of the need for future production from the area. The obstacle of need for immediate income indicates that the area of private profitability in the use of erosion-control practices may not extend to a level of soil loss as low as 5 tons per acre. Consequently, society is faced with the question of how far it should assume the cost of conserving the land resource productivity in an industry in which a surplus of output exists.

The goal of any particular government program should be considered in relation to other programs which affect the same resources. For example, price support programs which raise the price of cash crops relative to forage may offset the adoption of high forage rotations. The findings of this analysis indicated that there was a downward trend in the percent of land in row crops on farms in the area from 1949 to 1957. During much of this period, price supports on relatively erosive row crops were contingent upon an operator staying within an acreage allotment. Several operators and landlords pointed out that achievement of erosion control was retarded by the use of historical crop acreage in establishing acreage allotments. Several alternative programs could achieve more erosion control. One is a supply-control program based on land capability, rather than historical crop production. Another would consist of direct controls on the use of land with a specified erosion hazard, regardless of the price support program.

A relatively small proportion of the land in the sample was in the acreage reserve of the soil bank in 1957. Expansion of the Conservation Reserve Program of the soil bank has facilitated continuous forage production on many farms since 1957. A more permanent shift to forage production might be obtained through land use easements (40). Under a land use easement program, landowners would have the opportunity of selling their rights to produce specified crops. In areas with an erosion hazard like the one in the Ida-Monona soil association area, the government might purchase the rights to produce all crops except forages. Such a program could facilitate control of both soil erosion and the production of surplus crops.

Additional research is needed to refine estimates of the probable future land requirements by areas in the United States to serve as a guide in determining the total amount of soil erosion control needed. Evaluation of federal programs designed to shift land use, such as the easement approach, requires consideration of the comparative economic advantage of the area in various land uses over time if the nation's resources are to be allocated intertemporally in a manner approximating an optimum. This type of consideration is necessary also in determining the relative importance of various remedial measures leading to an assumed goal. For example, if the trend in forage production from 1949-57 in the Ida-Monona soil association area is indicative of the comparative advantage of forages in the area, more weight should be placed on remedial measures which would result in greater acceptance of Plan II. Even within the 5-ton-soil-loss goal there remains considerable flexibility in selecting a system of land use which would be consistent with the area's greatest comparative advantage or least comparative disadvantage.

Potential Remedies to Obstacles Which Prevent Operators From Adopting Erosion-Control Practices

Remedial action is possible to overcome some obstacles preventing attainment of the assumed goal of a 5-ton-per-acre soil loss.

OBSTACLE OF NEED FOR IMMEDIATE INCOME

Evidence of the obstacle of need for immediate income was found both in statistically significant farm characteristics and in the form of an explicit obstacle. Operators who expressed the obstacle also indicated what remedies might alleviate it. Table 55 shows that the remedies suggested paralleled the two basic causes of the obstacle—the high cash costs of adopting practices and their opportunity cost.

TABLE 55. REMEDIES TO OBSTACLE OF NEED FOR IMMEDIATE INCOME AS REPORTED BY FARM OPERATORS WHO CONSIDERED THIS AN OBSTACLE AND WERE IN A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Remedy	Number	Percent of 70 operators reporting obstacle
If tenant, develop a tenure arrangement which would reduce the uncertainty of not regaining the capital investments made during short periods of tenure	21	30
Establish a long-time program of soil erosion control so that the additional cash outlay during any 1 year is not large, and livestock can be raised on farm	10	14
If owner, include cost of erosion-control practices in the real estate loan and amortize it over a long period	10	14
Work off farm full-time to supplement farm income	8	11
If owner, amortize loans over a long period of time so that yearly principal and interest payments are small	6	10
More incentive payments from public agencies for erosion control practices	4	6
Other remedies	8	11

The alternative of off-farm work suggested by eight operators warrants careful consideration. On the basis of the statistical test to determine important farm characteristics, days of off-farm work explained a significant amount of variation in soil loss. Close proximity of the area to Sioux City, Council Bluffs and Omaha makes expansion of this alternative feasible. Concentrated effort by the United States Employment Service to inform farm people about part-time, seasonal and full-time job opportunities off the farm would aid some operators to overcome the obstacle of need for immediate income.

Another method of overcoming the obstacle would involve greater consideration of economics in formulating farm plans. One step in this direction would be to include in farm plans only those practices necessary to reduce erosion to the 5-ton-per-acre limit. Both the obstacle of insufficient roughage-consuming livestock and of amount or type of recommended practice provided insight into the fact that many erosion-control plans used in the study were not based on a thorough consideration of the economic factors involved.

The erosion-control plans were also seriously limited by their need for revision because of changes in technology between 1952 and 1957. Revision of the sample farm plans indicated that similar erosion-control plans for other farms in the area also were outdated by changes in physical technology and economic conditions. The large turnover in operators and owners of the sample farms, changes in the size of some sample farms and tenure changes on others all indicated that the erosion-control plans for many farms were outdated.

The limited resources of local offices of public agencies in the area have made the follow-up work of keeping farm plans current virtually impossible with the present methods of farm planning. Nevertheless, table 55 shows that farm operators favored long-term erosion-control-practice-adoption plans, thus making follow-up work extremely important.

The accuracy, completeness and low cost of farm planning with electronic computers recommend this as one possible method of enlarging the amount of erosion-control farm planning. A successful computational service for farm planning might require personnel in action agencies to work with farm operators in obtaining the necessary data and interpreting the results. If required data were made available, the capacity of electronic computers to handle large volumes of data would make it possible to revise farm plans as the need arose. A computational service could be provided by any centralized agency in a manner similar to the soil testing service provided by many land-grant colleges.

A major component of the obstacle of need for immediate income was the expectation of low returns relative to costs of erosion-control practices. Both owners and operators of many farms in the sample shared this expectation in 1957. A concentrated educational program to provide information about expected costs and returns of erosion-control practices would aid in overcoming this part of the obstacle. Additional research is needed, however, before reliable cost and return estimates can be made for farmers. Research initiated by the Agricultural Research Service, USDA and the Iowa Agricultural Experiment Station in 1959 will provide information about the effects of erosion-control practices and other production inputs on corn yields. Continuation of that inquiry to obtain data under various weather conditions will result in information that can be used in an educational program.

Additional research also is needed to determine the effects of changes in erosion on changes in land values over time. The 1957 analysis could be refined by obtaining actual sale prices of farms in the sample and analyzing the effects of soil loss and changes in soil loss on the changes in the actual market value of farmland.

After determination of the effects of various erosion-control practices on annual farm incomes and changes in land values, incentive payments would be needed for those practices not profitable for the individual operator. Information about the profitability of erosion-control practices also should indicate the amount of incentive payments required. Therefore, within the limits of the assumed goal, information about costs and returns of erosion-control practices could: (1) provide the basis for an educational program, (2) provide the basis for an incentive payments program and (3) aid farm planners to utilize effectively their flexibility in choosing practices to maximize the returns to individual operators.

Many operators interviewed said that need for immediate income was an obstacle to the adoption of the recommended rotations because of high real estate taxes. A variable tax rate based on soils data could be designed to provide an incentive for farmers to adopt erosion-control practices, particularly high forage rotations. These results could be accomplished by basing real estate taxes on use possibilities of soils and computing deviations in tax rates according to under- or over-utilization of the soils.

Low soil loss was related to well-financed and well-managed farms. Efforts to aid farmers in adjusting to more economical size units as well as improving the management of their units should result in lower soil loss in the area. While many participants appear to have these two characteristics, further research into factors responsible for participation in the Soil Conservation District Program is needed to suggest methods of expanding it to include more farmers.

OBSTACLE OF FAILURE TO SEE THE NEED FOR RECOMMENDED EROSION-CONTROL PRACTICE—CUSTOM AND INERTIA

The statistically significant characteristic of Soil Conservation District Program participation indicated that farm operators with erosion-control plans have recognized the seriousness of the erosion-control problem. The significance of recognition of the problem as a characteristic explaining soil loss further affirmed its importance. Also, failure to see the need for a recommended practice plus custom and inertia was a significant obstacle preventing reduction of soil losses. Consequently, remedial action is contingent upon the ability of farm operators and owners to see the need for erosion-control practices.

Additional research is needed to determine why some operators have vague and illogical reasons for resisting the practices. Interdisciplinary research by economists, sociologists, anthropologists and psychologists is necessary before detailed reasons and remedies can be specified for the obstacle. One method of obtaining this information might be with the use of depth interviews by a sociologist working with an economist when the next phase of the research in this series is undertaken.

The statistically significant characteristic of recognition of the seriousness of the problem suggested that any program which brought about this recognition will facilitate the adoption of erosion-control practices. One such program which was being initiated in 1957 was the small watershed approach. Some of the operators in the sample said that community pressure brought to bear on a few individuals frequently resulted in their changing from an erosive to a non-erosive system of farming in the watershed. Much of the success of the watershed approach depends, however, upon the number and effectiveness of its leaders in the community (4). Action agencies need to work through community leaders who have the resourcefulness and community status to bring the undertaking to a successful conclusion. A majority of the farm operators interviewed said that they preferred that neighboring farmers provide the leadership for such things as conservation work days rather than anyone else, including action agency personnel. In some cases, operators suggested co-leaders, one neighboring farmer and one representative of an action agency. Consequently, the watershed approach which utilizes community leadership can be expected to create awareness of the need for remedial action. Direct public assistance, under Public Law 566 or pooling arrangements in the Agricultural Conservation Program, appears to facilitate the watershed approach to erosion control, also.

OBSTACLE OF FIELD AND ROAD LAYOUT

The relationship of the obstacle of field and road layout suggested that further research is necessary to determine methods of modifying some erosion-control practices. Farm operators frequently stated that terraces would be acceptable if they were laid out in parallel fashion. Further research concerning the physical possibilities and economic feasibility of parallel terracing and cut and fill terraces may provide information for educational programs which will help overcome this obstacle. An inquiry into the economics of land-forming practices undertaken by the Agricultural Research Service, USDA, and the Iowa Agricultural Experiment Station will provide insight into this problem.

Another method of relieving the obstacle of field and road layout would be an educational program to inform landowners how to appraise and transfer small tracts of land which could be farmed on the contour more easily by neighboring farmers than by present owners.

In 1957, the Crawford County Agricultural Conservation Program made incentive payments for the practice of changing fences to conform to the contour. This use of incentive payments might result in more erosion control than many other practices eligible for such payments in the area. The importance of the obstacle of field and road layout underscores the need for extension of such payments in additional counties.

OTHER OBSTACLES WHICH WERE NOT STATISTICALLY SIGNIFICANT IN 1957

In addition to those obstacles which had a statistically significant effect on soil loss, 12 other obstacles were reported by operators in the sample. The most frequently found obstacle which was not statistically significant, amount or kind of recommended practice, might be overcome in one of three ways. Remedial measures designed to educate owners and operators on the need for erosion-control practices would help to overcome the obstacle for those unaware of the magnitude of the problem. A second remedial measure would consist of giving farm operators and owners as much flexibility as possible in selecting among alternative practices, particularly rotations and terraces. A refined method of farm planning, using the farmer's choice of practices and more complete information about the costs and returns of practices, would encompass a maximum amount of flexibility. A third method of alleviating the obstacle would be to include in farm plans only the practices necessary to reduce soil loss to 5 tons per acre.

Since the obstacle of insufficient roughage-consuming livestock was important in 1949 and closely related to the obstacle of need for immediate income, operators reporting the obstacle in 1957 were asked to suggest possible remedies for overcoming it (table 56). The remedies suggested would overcome the two basic parts of the income obstacle—the high costs of practices and the opportunity cost of adopting them. Suggested methods of overcoming high cash costs were gradual accumulation of roughage-consuming livestock, availability of long-term livestock loans and the use of livestock-crop share leases. Possible remedies for the opportunity cost aspect of the obstacle were a price support program for livestock and creation of a better market for livestock products.

Another obstacle which has persisted in importance over time is rental arrangement and lack of landowner's cooperation. The 25 operators reporting this obstacle in 1957 were asked to suggest possible remedies for it. More than half of them said that an educational program informing landlords of the need for erosion control would be the best method of overcoming the obstacle (table 57). Other suggested remedies dealt primarily with improvements in leases to assure sharing in equal proportions the costs and returns of erosion-control practices over time.

Since the obstacle of small size of farm was important in 1949, operators were asked to suggest remedies for it if the obstacle occurred on their farm in 1957 (table 58). Only 10 operators recorded the obstacle in 1957, and half of them suggested part-time work off the farm as a method of supplementing their farm income. Another suggested remedy called for operators to increase their business volume through expanded livestock or crop enterprises.

TABLE 56. REMEDIES TO OBSTACLE OF AMOUNT AND KIND OF LIVESTOCK ON FARMS REPORTED BY FARM OPERATORS WHO CONSIDERED IT AN OBSTACLE IN A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Remedy	Number	Percent of 51 operators reporting obstacle
Purchase young calves to be roughage fed	14	27
A price support program to remove some of the risk involved with livestock	14	27
Wait until livestock prices drop	6	12
Wait until money is accumulated to buy livestock	5	10
More credit available for long-term loans	4	8
Creation of a market in the area for grade A milk by some action agency	3	6
Use a crop-livestock share lease	3	6
Other remedies	7	14

TABLE 57. REMEDIES TO OBSTACLE OF RENTAL ARRANGEMENT AND LANDLORD'S COOPERATION AS REPORTED BY FARM OPERATORS WHO CONSIDERED THIS AN OBSTACLE IN A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Remedy	Number	Percent of 25 operators reporting obstacle
An educational program informing landlords of need for soil erosion control	13	52
A lease that would provide for sharing the costs of erosion-control practices according to the benefits operator and landlord receive	5	20
A lease providing for tenure longer than 1 year	4	16
A lease providing reimbursement to operator for unused portion of erosion-control practices if he were to move	4	16
Rent another farm	4	16
A lease that would provide sharing the costs of the erosion-control practices by letting the landlord furnish materials and the operator furnish labor	3	12
A crop-share lease including extra rental rates for related improvements such as buildings for livestock	2	8
A lease that would include adjustable cash or share rents for installing "soil building" rotations and practices	2	8
Other remedies	3	12

TABLE 58. REMEDIES TO OBSTACLE OF SIZE OF FARM AS REPORTED BY FARM OPERATORS IN A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Remedy	Number	Percent of 10 operators reporting obstacle
Work off the farm part-time to supplement the farm income	5	50
Increase size of business through production of livestock on purchased feed	3	33
Wait until capital is accumulated for a down payment on a larger farm	2	20
Work off the farm full-time to supplement the farm income	1	10
Wait until additional land is available for renting	1	10
Other remedies	2	20

The remaining obstacles reported by relatively small numbers of farm operators would be alleviated in large measure by remedying the most important obstacles previously mentioned. Research should be continued to analyze obstacles as they vary in importance.

POSSIBLE METHODS OF OVERCOMING NONOPERATING LANDOWNERS' OBSTACLES TO EROSION CONTROL

Further analysis is needed to determine which, if any, obstacles voiced by nonoperating landowners are statistically significant in explaining variations in soil loss. The findings of this analysis, with respect to identifying these obstacles, were not as conclusive as might be desired from a research viewpoint. Although not statistically significant, two obstacles did appear to be the most important ones voiced by nonoperating landowners. Evidence of the importance of these obstacles was found in the frequency with which they were mentioned, the relatively high soil loss on farms where they occurred, statements made by tenants on the farms and characteristics of nonoperating landowners which were statistically significant in explaining variations in soil loss on their farms.

OBSTACLE OF NEED FOR IMMEDIATE INCOME

Although the need for immediate income was not statistically significant, several statistically significant characteristics of nonoperating landowners substantiated the importance of the obstacle. These characteristics were additional acres owned, need to borrow funds for erosion-control practices and the operator's obstacle of need for immediate income.

Many of the remedial measures suggested for resolving the obstacle of need for immediate income for farm operators also could apply to nonoperating landowners. Inclusion of the costs of erosion-control practices in real estate loans, additional consideration to economic factors in developing farm plans, research and education about the economic effects of erosion-control practices and consideration of the effects of other government programs on erosion control would help owners alleviate the need for immediate income.

Since some of the sample farms were tenant-operated, part of the remedies to obstacles have to be differentiated from those remedies suggested for owner-operators. Owners with relatively short planning horizons because of their advanced years require emphasis on either (1) erosion-control practices which require small cash outlays and do not substantially affect farm income or (2) compensation provisions in leases to assure tenants that they will receive an adequate return on investments which they might make in erosion-control practices. The former remedy should be considered in the farm planning process, while the latter requires emphasis on improvements in farm leases by action agencies. Model lease forms which include alternative types of compensation provisions for unexhausted investments in erosion-control practices need to be prepared. In turn, these should be made available to tenants and nonoperating landowners by action agencies which are attempting to get erosion-control practices adopted on tenant-operated farms.

In special cases, more restrictive measures are required. On several tenant-operated farms in the sample, the owner was so old that he was no longer capable of managing the business. On some of these farms, operators with short planning horizons were exploiting the land to the extent that economically irreversible damage had been done to the land resource. In these cases, it appeared that the public interest was jeopardized. Consequently, control measures by public institutions may be necessary to protect the public interest in privately owned land. Legislation which would establish upper limits on the allowable amount of erosion would prevent permanent damage. Additional research is needed to determine the extent of erosion which can be tolerated without unduly curtailing the freedom of individual landowners. Institutions for controlling land use to prevent the destruction of the public interest in privately owned land need further study. Some institutions which should be considered are real estate taxes, rural zoning with compensation provisions through grants in aid from the federal government and a specified minimum soil loss requirement to qualify farm operators for any form of agricultural payments from the federal government.

OBSTACLE OF INSUFFICIENT ROUGHAGE-CONSUMING LIVESTOCK

Although not statistically significant, the obstacle of insufficient roughage-consuming livestock was frequently mentioned by nonoperating owners of farms with soil losses which tended to be above the sample soil loss mean. Several methods were used to prevent this obstacle by some landowners in the sample. These success elements included both livestock-crop share leases and favorable rental rates to tenants for including relatively large amounts of forages in their rotations. An educational program by action agencies to inform owners and operators of methods of preparing livestock-crop share leases would aid other owners and operators to overcome the obstacle. Appreciation of the seriousness of the erosion-control problem appears to be a prerequisite to get owners to provide incentives to tenants through differential rental rates for the production of forage. Also, programs which provide incentives for the adoption of high forage rotations through subsidy payments would help to overcome this obstacle. In addition, research and education programs to inform nonoperating landowners of the relative profitability of including livestock in their farm plans will facilitate the adoption of high forage rotations.

Many remedial measures suggested for obstacles preventing the adoption of erosion-control practices by operators also apply, with slight modifications, to owners. Flexibility in selection of erosion-control practices is particularly important in finding combinations of practices upon which both operators and owners of tenant-operated farms will agree. Since one of the statistically significant characteristics explaining soil loss on tenant-operated farms was the security of tenure as reflected by the chance of the owner owning the farm at least one more year after the date of interview, erosion-control practices which require small cash outlays (contouring, strip cropping and contour listing) are likely to be acceptable on tenant-operated farms where the probability of continued ownership is low.

Statistical tests indicated that some farm characteristics which could be adapted to other farm situations were related to low soil losses. As a result, the first remedial hypothesis—if there are obstacles which have prevented the reduction of erosion losses to 5 tons per acre per year or less, then there are success elements on farms where erosion losses have been reducd which can be adapted to farms with high soil losses—was accepted. The nature of observed obstacles and characteristics on farms in the area indicated that the remedial measures previously suggested would expedite the adoption of erosion-control practices. Consequently, the second remedial hypothesis — if there are obstacles which have prevented a reduction of erosion control losses to 5 tons per acre per year or less, then there are potential remedial measures dormant in the problematic situation which can be developed to overcome these obstacles — was accepted. Final testing of these remedial measures must await their use and consequent effects on soil loss over time.

APPENDIX A: DEFINITION OF SOIL EROSION CONTROL

Although scientists have been developing definitions of soil conservation for more than 50 years, vague, ambiguous and conflicting definitions still persist. Heady and Scoville have defined soil conservation as the prevention of diminution of future production on a given area of soil and from a given input of labor and capital apart from the conservation resource input, and with the technique of production otherwise constant (18, p. 375). The planning guide prepared by the Soil Conservation Service and the practices eligible for cost sharing under the Agricultural Conservation Program, however, include a number of land use practices which have little, if any, effect in preventing the diminution of future production on a given area of soil (33).

In an attempt to avoid some of the confusion of terms, soil erosion control rather than soil conservation has been adopted in this inquiry. The term "soil erosion control" is more meaningful in conveying the interpretation of soil conservation as prevention of the deterioration of the productive capacity of the soil. Soil erosion control is defined here to be the prevention of diminution of the discounted value of future production from a given area of soil, a given level of expected production technology, a given discounted value of labor and capital, exclusive of the value of the soil-erosion-control input.

This definition of erosion control is partially explained in fig. A-1. Although empirical derivation of such a model at the national level has been impracticable because of data and aggregation problems, a returns surface showing aggregate input-output relationships is useful as a frame of reference because it encompasses some social costs of the time distribution of use of resources.

The model seems more realistic when applied at a microlevel: for instance, to an acre of land with a moderately severe erosion hazard in western Iowa.[31] Although empirical evidence is not available for this particular model, it can be hypothesized that the actual returns surface is similar to that in fig. A-1. In this instance, the value of output is represented by the discounted value of expected future income during the relevant planning horizon from the resources employed, for example, maximum output BC results from inputs OA and OD. When erosion-control inputs are increased from O to F, output goes through a stage of increasing returns between D and H. The area of increasing returns is coincident with the prevention of erosion exceeding the level of economic irreversibility.[32]

Conceivably, gully erosion could proceed to such an extreme that it would be economically impossible

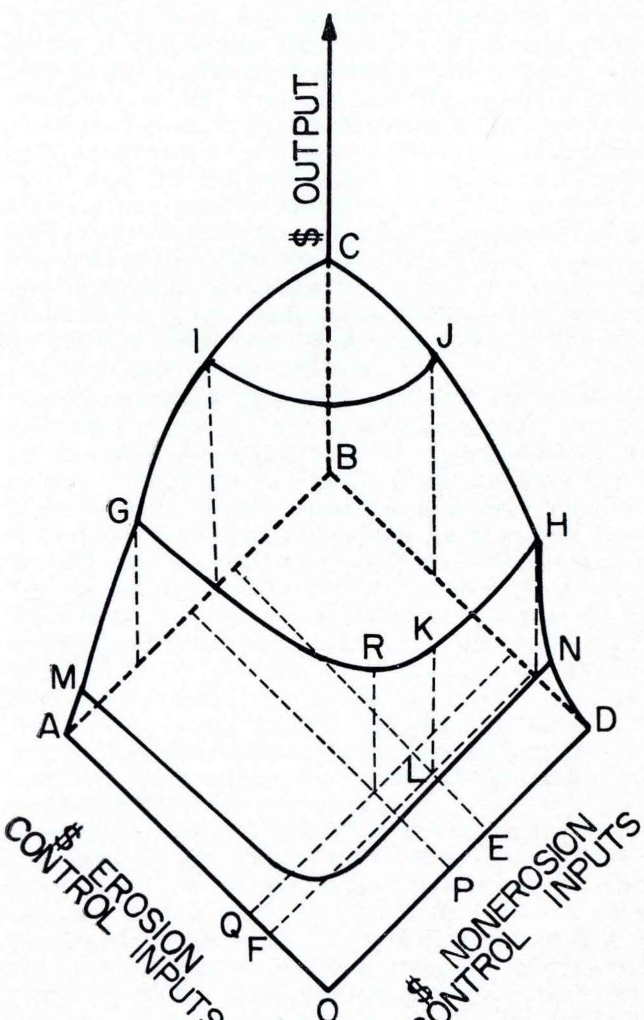

Fig. A-1. A conceptual returns surface reflecting production resulting from combinations of erosion-control inputs and nonerosion-control inputs, expressed in discounted monetary terms at one point in time.

[31] Static production surfaces have been empirically derived by Heady *et al.* (17, pp. 293-302).

[32] Economic irreversibility is the point at which the anticipated discounted marginal costs of restoring the physical productivity of the resource exceed the discounted marginal returns expected to accrue to the factor plus its salvage value. For a given resource, this point varies by time periods as a result of changes in (1) demand for the factor, (2) rate of discount, (3) costs of resource restoration and (4) other production costs.

to produce a given value of output. If sufficient erosion-control inputs are employed, however, the possibility of passing the point of economic irreversibility is avoided. At a low level of output, isoquant MN, there is nearly perfect complementarity between erosion-control and nonerosion-control inputs. At higher levels, above isoquant GH, erosion- and nonerosion-control inputs probably can be substituted for each other over a wide range. As maximum output is approached, the range of substitution narrows again until the maximum output can be produced by only one combination of inputs. Throughout the surface, the economic problem is to produce the desired output with minimum cost; (in this instance) that point is the minimum sum of the distances from the origin on both axes.

The shape of the returns surface is determined by many factors including the physical productivity of capital and labor inputs, the price level, the length of the planning horizon, the renewability of the natural resource and the rate of discount assumed. Although the surface is fixed at one point in time, it can change between time periods. For example, as technology increases the productivity of nonerosion-control inputs, the surface rises, leaning particularly to the left. As the ratio of present to expected future prices decreases, the surface rises in favor of erosion-control inputs. When the planning horizon shortens, the marginal and average revenues to erosion-control inputs fall, and the surface shifts to the left. There are many combinations of these, as well as other factors, which conceivably could alter any given surface.

Although the model is static, it must be corrected through time as estimates improve and knowledge grows. Yet decisions of resource allocation must be made in one time period for which a response surface can be estimated for a given resource situation. In many instances, these decisions can be only tentative. Hence, as the surface shifts, some resources can be reallocated. Nevertheless, the optimum combination of erosion- and nonerosion-control inputs will depend upon the portion of the returns surface relevant at a point in time to the decision maker, either an individual firm manager or a representative of society.

An understanding of the nature of the expected surface would aid in decision making. Individual farmers would find it useful in choosing between erosion-control and nonerosion-control inputs, such as terraces and machinery. Groups of farmers must evaluate alternatives, such as boar testing stations versus watersheds. Representatives of society must decide between possible uses of funds, for example, between research and conservation. Regardless of who makes the decision, response surfaces at varying levels of aggregation are theoretically applicable. Consideration with an explicit model rather than implicit assumptions is needed in allocating erosion-control and nonerosion-control inputs more wisely.

Two additional characteristics of the model are important. The first, which may be seen in fig. A-1, is that a given level of output over time, indicated by an isoquant, can be produced with many combinations of erosion-control and nonerosion-control inputs. The second characteristic is the time distribution of output for any point on the surface. Above the point of economic irreversibility, many different combinations of inputs over time will result in a given sum of discounted output. A detailed elaboration on these two characteristics would require more time than allotted here. Suffice it to say that substitution relationships are crucial in determining the inputs needed to produce the total output summed over time, as well as the occurrence of that output by time periods within the planning horizon.

If soil erosion exceeds the level desired by society, that is if in the national model the discounted expected output for the planning horizon is at a point on an isoquant above that which can be achieved with present resource use, the public goal can be accomplished in either, or both, of two ways. First, resources (erosion control and nonerosion control) now used in the agricultural industry can be reallocated according to their marginal productivities to achieve the desired summed total of output for the entire planning horizon. Second, additional resources in the form of incentive payments, education, research or private funds can be added to the present resource base. Both alternatives have implications for soil erosion control and agricultural adjustment by influencing the total output and the time distribution of the output.[33]

[33] The efficiency of the industry might be increased by maintaining a given level of output but by reallocating the inputs among erosion-control and nonerosion-control inputs. Also, if necessary, output could be reduced by reallocating inputs within and between industries.

APPENDIX B: TESTS OF SIGNIFICANCE

Determination of the probability that the difference in the soil loss means for farms with and without an obstacle was not due to chance necessitated the use of several statistical tests. By assuming no appreciable sampling error and independence of obstacles in their effects on soil losses, a "t" test with pooled variance was considered applicable (38, pp. 90-92).

The hypothesis that the mean soil loss for farms with each obstacle was the same as the mean soil loss for farms without the obstacle was tested by computing the statistic

$$t = ({}_1\bar{x} - {}_0\bar{x}) \sqrt{\frac{0^n 1^n (0^n + 1^n - 2)}{({}_0n + {}_1n)\Sigma x^2}}$$

and comparing it with the tabulated value of Students' t distribution for the desired probability level with the appropriate degrees of freedom. Where

${}_1\bar{x} = \frac{\Sigma_1 X}{\Sigma_1 n}$, the mean soil loss for farms with the obstacle,

${}_0\bar{x} = \frac{\Sigma_0 X}{{}_0 n}$, the mean soil loss for farms without the obstacle,

n = number of farms,

X = soil loss per farm,

$\Sigma x^2 = \Sigma_0 X^2 - \frac{(\Sigma_0 X)^2}{{}_0 n} + \Sigma_1 X^2 - \frac{(\Sigma_1 X)^2}{{}_1 n}$, the pooled sum of squares, and the subscript prefixes 1 and 0 indicate farms with and without the obstacle, respectively.

To obtain comparable results with those obtained in 1949, similar statistical techniques were used. In 1949 Frey (14, pp. 1006-1007) tested the difference in the soil loss means for farms with each obstacle and for those without the obstacle while including an allowance for the sampling error. This procedure was repeated for the data obtained in 1957. Determination of significant differences in means by this method assumes independence of obstacles in their effects on soil losses.

The hypothesis that the mean soil loss for farms with each obstacle and those without the obstacle are the same was tested by computing the statistic

$$t = \frac{{}_1\bar{X} - {}_0\bar{X}}{S_{{}_1\bar{x} - {}_0\bar{x}}}$$

and comparing it with the tabulated value of Students' t distribution for the desired probability level with the appropriate degrees of freedom. Where

${}_1\bar{X} = \frac{\Sigma_1 X_{ijk}}{{}_1 n_0}$, the mean loss for farms with the obstacle,

${}_0\bar{X} = \frac{\Sigma_0 X_{ijk}}{{}_0 n_0}$, the mean loss for farms without the obstacle,

X_{ijk} = the soil loss for the *kth* farm in the *jth* sampling unit of the *ith* stratum,

$S_{{}_1\bar{x} - {}_0\bar{x}} = \sqrt{\hat{V}({}_1\bar{X}) + \hat{V}({}_0\bar{X})}$, the variance of the difference of the means,

$$\hat{V}_1(\bar{X}) = \frac{({}_1\bar{X})^2}{{}_1 n_0} \left[\frac{S^2 x}{(1/{}_1 n_0 \Sigma_1 X_{ijk})^2} + \frac{S^2 f}{\left[\frac{1^f 0}{1^n 0}\right]^2} - 2 \frac{Sxf}{(1/{}_1 n_0 \Sigma_1 X_{ijk}) \frac{1^f 0}{1^n 0}} \right],$$

$1^n 0$ = the number of sampling units containing farms with the obstacle,

$S^2{}_x$ = the within-stratum mean squares for soil loss on farms with the obstacle,

$S^2{}_f$ = the within-stratum mean squares for number of farms with the obstacle,

S_{xf} = the covariance for soil loss and number of farms with the obstacle,

$1^f 0$ = the number of farms with the obstacle, and

$\hat{V}({}_0\bar{X})$ is computed in an analogous manner to $\hat{V}({}_1\bar{X})$.

This "t" test has two major limitations. It ignores the covariance between farms with and without each obstacle. Also, the method fails to consider the effect that one obstacle may have on another in influencing soil loss. The latter limitation was considered more serious than the former. Consequently, linear regression also was used in testing the significance of obstacles on soil loss. The hypothesis that the regression coefficient, b, for each obstacle is equal to 0 was tested by computing the statistic

$$t = \frac{b - 0}{S_b}$$

and comparing it with the tabulated value of Students' t distribution for the desired probability level with the appropriate degrees of freedom,[34] where

b = the regression coefficient for each obstacle,

S_b = the standard error of each regression coefficient,

$Y = (f)a + bx_1 + bx_2 + \ldots + bx_{16}$,

Y = soil loss for the sample of 138 farms,

a = an over-all mean, and

$x_1 \ldots x_{16}$ = obstacle 1 . . . 16 (entered in regression problem as 1 if obstacle was present on the farm or 0 if it was not present).

If the interaction among obstacles is ignored, however, it would be possible to consider the covariance between farms with and without each obstacle. As with the technique used by Frey, the hypothesis that the soil loss means for farms with each obstacle and those without the obstacle are the same could be tested by computing the statistic

$$t = \frac{{}^1\bar{X} - {}_0\bar{X}}{S_1\bar{x} - 0\bar{x}}$$

and comparing it with the tabulated value of Students' t distribution for the desired probability level with the appropriate degrees of freedom. Where

$$\bar{X} = \frac{\Sigma X_{ij}}{n}\text{, the mean soil loss,}$$

X_{ij} = the soil loss for farms in the *ith* stratum, in the *jth* sampling unit (either 1 or 2),

$$S_1\bar{x} - {}_0\bar{x} = 1/4 \sum_i \left\{ \frac{1}{{}_1\bar{n}^2} \left[({}_1X_{i1} - {}_1X_{i2})^2 + {}_1X^2 \right.\right.$$

$$\left.\left. ({}_1n_{i1} - {}_1n_{i2})^2 - 2{}_1\bar{X}({}_1X_{i1} - {}_1X_{i2})({}_1n_{i1} - {}_1n_{i2}) \right] \right\} + 1/4 \sum_i \left\{ \frac{1}{{}_0\bar{n}^2} \left[({}_0X_{i1} - {}_0X_{i2})^2 + {}_0\bar{X}^2 ({}_0n_{i1} - \right.\right.$$

$$\left.\left. {}_0n_{i2})^2 - 2{}_0\bar{X}({}_0X_{i1} - {}_0X_{i2})({}_0n_{i1} - {}_0n_{i2}) \right]\right\} - \frac{1}{{}_1\bar{n}}\,\frac{1}{{}_0\bar{n}}$$

$$\sum_i \Big\{ ({}_1X_{i1}\ {}_0X_{i1} - {}_0X\ {}_1X_{i1}\ {}_0n_{i1} - {}_1X_{i1}\ {}_0X_{i2}$$

$$+ {}_0\bar{X}\ {}_1X_{i1}\ {}_0n_{i2}) + \Big[({}_1X_{i1} - {}_1\bar{X}\ {}_1n_{i1}) - {}_1X_{i2}$$

$$- {}_1\bar{X}\ {}_1n_{i2}) \Big] + \Big[({}_0X_{i1} - {}_0\bar{X}\ {}_0n_{i1}) - ({}_0X_{i2} - {}_0\bar{X}$$

$${}_0n_{i2}) \Big] + \Big[({}_1X_{i1} - {}_1\bar{X}\ {}_1n_{i1}) - ({}_1x_{i2} - {}_1\bar{X}\ {}_1n_{i2}) \Big]$$

$$\Big[({}_0X_{i1} - {}_0\bar{X}\ {}_0n_{i1}) - ({}_0X_{12} - {}_0\bar{X}\ {}_0n_{12}) \Big] \Big\}\text{, the}$$

variance of the difference of the means, ${}_1\bar{X} - {}_0\bar{X}$,

n = number of sampling units,

$\bar{n}$ = mean number of sampling units,

and the subscript prefixes 1 and 0 indicate farms with and without the obstacle, respectively. Since the interaction between obstacles appeared too important to be ignored, this form of statistical analysis was not utilized.

[34] Jebe, E. H., Ames, Iowa. Recommendations for statistical analysis. (Private communication.) 1959.

APPENDIX C: SUPPLEMENTAL TABLES

TABLE C-1. A COMPARISON OF BROWNING FACTORS USED IN ESTIMATING SOIL LOSSES IN WESTERN IOWA IN 1949-52 AND 1957.

	1949-52 factor	1957 factor
Management		
Poor	1.3	1.3
Medium	1.0	1.0
Good	0.7	0.7
Special practices		
Rows up and down hill cultivation	1.0	1.0
Contour cultivation		
2.0-7.0 percent slope	0.5	0.5
7.1-12.0 percent slope	0.5	0.6
12.1-18.0 percent slope	0.5	0.7
18.1-24.0 percent slope	0.5	0.8
Contour listing		
2-0-12.0 percent slope	0.25	0.2
12.1-18.0 percent slope	0.25	0.3
Strip cropping, surface planted		
2.0-12.0 percent slope	0.25	0.2
12.1-18.0 percent slope	0.25	0.3
Terracing		
2.0-7.0 percent slope	0.15	0.1
7.1-12.0 percent slope	0.15	0.1
12.1-18.0 percent slope		0.2
18.1-24.0 percent slope		0.2
Across hill cultivation		
2.0-12.0 percent slope	0.7	0.8
12.1-24.0 percent slope	0.7	0.9
Contour listing on terraced land		
2.0-12.0 percent slope	0.05	0.05
12.1-24.0 percent slope	0.05	0.1
Rotations		
Corn, continuous	4.0	3.4
CCO	3.0	2.8
CCO_c	2.0	2.4
CO	2.0	2.5
CO_c	1.5	2.0
CCOM	1.4	1.4
$COMCO_{sc1}$	1.2	1.3
COM	1.0	0.9
CCOMM	0.9	1.0
CCOMMM	0.8	0.8
COMM	0.6	0.6
COMMM	0.4	0.5
COMMMM	0.3	0.4
COMMMMM	0.2	0.3
Topography		
Class I		
All soils	0.087	0.1
Class II		
Monona-Napier-Castana	0.734	0.6
Monona-Napier	0.734	0.6
Monona	0.734	0.6
Monona-Malvern	0.802	0.7
Ida-Monona-Napier	0.818	0.7
Monona-Turin	0.825	0.7
Monona-Shelby	0.826	0.7
Monona-Steinauer	0.826	0.7
Monona-Burchard	0.835	0.7
Monona-Forbes-Castana	0.835	0.7
Monona-Ute	0.835	0.7
Monona-Castana	0.835	0.7
Monona-Dow	0.873	0.8
Ida-Napier-Castana	0.873	0.8
Ida-Napier	0.873	0.8
Ida-Monona	0.873	0.8
Ida-Monona-Shelby	0.907	0.7
Ida-Monona-Castana	0.915	0.8
Ida-Malvern	1.044	0.9
Ida-Steinauer	1.080	0.9
Ida-Shelby	1.080	0.9
Ida-Turin	1.080	0.9
Ida-Forbes-Castana	1.080	0.9
Ida-Burchard	1.094	0.9
Ida-Ute	1.094	0.9
Ida-Castana	1.094	0.9
Ida-Dow	1.152	1.0
Ida	1.152	1.0
Class III		
Monona	2.025	1.9
Monona-Forbes-Castana	2.025	1.9
Monona-Castana	2.025	1.9
Monona-Ute	2.035	1.9
Monona-Burchard	2.093	2.0
Monona-Turin	2.194	1.9
Monona-Malvern	2.200	2.0
Monona-Ida-Castana	2.250	2.1
Monona-Shelby	2.307	1.8
Monona-Steinauer	2.307	2.0
Monona-Ida-Shelby	2.331	2.0
Monona-Dow	2.363	2.2
Ida-Burchard	2.363	2.2
Ida-Monona	2.363	2.2
Ida-Malvern	2.470	2.2
Ida-Turin	2.531	2.2
Ida-Steinauer	2.577	2.2
Ida-Shelby	2.577	2.2
Ida-Forbes-Castana	2.613	2.2
Ida-Ute	2.613	2.2
Ida-Castana	2.613	2.2
Ida-Dow	2.700	2.4
Ida	2.700	2.4
Class IV		
Burchard	2.317	2.2
Malvern	2.510	2.2
Shelby	2.703	1.8
Castana	4.497	4.7
Ute	4.497	4.7
Forbes-Castana	4.497	4.7
Monona	4.947	4.7
Monona-Castana	4.947	4.7
Monona-Ute	4.947	4.7
Monona-Forbes-Castana	4.947	4.7
Monona-Turin	5.359	4.7
Ida-Monona-Castana	5.496	5.1
Ida-Forbes-Castana	5.770	5.3
Ida-Ute	5.770	5.3
Ida-Castana	5.770	5.3
Monona-Ida	5.771	5.2
Monona-Dow	5.771	5.2
Ida-Monona-Turin	5.771	5.2
Turin	5.772	4.7
Ida-Monona-Dow	6.046	5.4
Ida-Turin	6.183	5.3
Ida-Dow	6.595	5.8
Dow	6.595	5.8
Ida	6.595	5.8

TABLE C-2. OPERATORS' CHARACTERISTICS AND OBSTACLES ON 18 FARMS WHERE SOIL LOSSES INCREASED MORE THAN 5 TONS PER ACRE FROM 1949-57 ON A SAMPLE OF FARMS IN WESTERN IOWA, 1957.

Item	Units	Group mean	Sample mean
Soil loss per farm	(tons per acre)	29.2	14.1
Topographic rating per farm	(index number)	2.9	2.5
Soil conservation district participation			
Complete cooperator	(percent)	11	33
Initial cooperator	(percent)	17	17
Noncooperator	(percent)	72	50
Operators' estimate of seriousness of problem			
Major problem	(percent)	22	43
Somewhat of a problem	(percent)	39	34
No problem	(percent)	39	23
Days off-farm employment			
None	(percent)	78	65
1 to 159	(percent)	17	22
160 and over	(percent)	5	13
Operators with ability to borrow funds for erosion-control practices	(percent)	55	70
Acres farmed per operator	(acres)	165	214
Animal units per farm	(animal units)	17.9	33.2
Type of tenure			
Owner-operator	(percent)	61	49
Part-owner	(percent)	6	12
Tenant	(percent)	33	39
Operator's obstacles			
Need for immediate income	(percent)	61	51
Custom and failure to see need	(percent)	78	42
Rental arrangement and lack of landowner's cooperation	(percent)	11	18
Insufficient roughage-consuming livestock	(percent)	50	37

TABLE C-3. OPERATORS' CHARACTERISTICS AND OBSTACLES ON 13 FARMS WHERE SOIL LOSSES CHANGED LESS THAN 5 TONS PER ACRE BETWEEN 1949 AND 1957 AND WERE ABOVE THE SAMPLE MEAN IN 1957 AND ON A SAMPLE OF FARMS IN WESTERN IOWA.

Item	Units	Group mean	Sample mean
Soil loss per farm	(tons per acre)	21.0	14.1
Topographic rating per farm	(index number)	2.8	2.5
Soil conservation district participation			
Complete cooperator	(percent)	46	33
Initial cooperator	(percent)	8	17
Noncooperator	(percent)	46	50
Operator's estimate of seriousness of problem			
Major problem	(percent)	54	43
Somewhat of a problem	(percent)	23	34
No problem	(percent)	23	23
Days off-farm employment			
None	(percent)	77	65
1 to 159	(percent)	15	22
160 and over	(percent)	8	13
Operators with ability to borrow funds for erosion-control practices	(percent)	38	70
Acres farmed per operator	(acres)	222	214
Animal units per farm	(animal units)	22	33.2
Type of tenure			
Owner-operator	(percent)	38	49
Part-owner	(percent)	8	12
Tenant	(percent)	54	39
Operator's obstacles			
Need for immediate income	(percent)	62	51
Custom and failure to see need	(percent)	23	42
Rental arrangement and lack of landowner's cooperation	(percent)	23	18
Insufficient roughage-consuming livestock	(percent)	38	37

TABLE C-4. OPERATORS' CHARACTERISTICS AND OBSTACLES ON 26 FARMS WHERE THERE WERE NO EFFECTIVE OBSTACLES IN 1957 AND ON A SAMPLE OF FARMS IN WESTERN IOWA.

Item	Units	Group mean	Sample mean
Soil loss per farm	(tons per acre)	10.8	14.1
Topographic rating per farm	(index number)	2.8	2.5
Soil conservation district participation			
Complete cooperator	(percent)	69	33
Initial cooperator	(percent)	0	17
Noncooperator	(percent)	31	50
Operator's estimate of seriousness of problem			
Major problem	(percent)	61	43
Somewhat of a problem	(percent)	31	34
No problem	(percent)	8	23
Days off-farm employment			
None	(percent)	66	65
1 to 159	(percent)	19	22
160 and over	(percent)	15	13
Operators with ability to borrow funds for erosion-control practices	(percent)	69	70
Acres farmed per operator	(acres)	230	214
Animal units per farm	(animal units)	34.2	33.2
Type of tenure			
Owner-operator	(percent)	54	49
Part-owner	(percent)	15	12
Tenant	(percent)	31	39
Operator's obstacles			
Need for immediate income	(percent)	23	51
Custom and failure to see need	(percent)	0	42
Rental arrangement and lack of landowner's cooperation	(percent)	0	18
Insufficient roughage-consuming livestock	(percent)	19	37

TABLE C-5. OPERATORS' CHARACTERISTICS AND OBSTACLES ON 27 FARMS WHERE SOIL LOSSES WERE LESS THAN 5 TONS PER ACRE IN 1957 AND ON A SAMPLE OF FARMS IN WESTERN IOWA.

Item	Units	Group mean	Sample mean
Soil loss per farm	(tons per acre)	3.4	14.1
Topographic rating per farm	(index number)	1.6	2.5
Soil conservation district participation			
Complete cooperator	(percent)	63	33
Initial cooperator	(percent)	11	17
Noncooperator	(percent)	26	50
Operator's estimate of seriousness of problem			
Major problem	(percent)	41	43
Somewhat of a problem	(percent)	33	34
No problem	(percent)	26	23
Days off-farm employment			
None	(percent)	74	65
1 to 159	(percent)	11	22
160 and over	(percent)	15	13
Operators with ability to borrow funds for erosion-control practices	(percent)	93	70
Acres farmed per operator	(acres)	262	214
Animal units per farm	(animal units)	76.3	33.2
Type of tenure			
Owner-operator	(percent)	59	49
Part-owner	(percent)	15	12
Tenant	(percent)	26	39
Operator's obstacles			
Need for immediate income	(percent)	26	51
Custom and failure to see need	(percent)	0	42
Rental arrangement and lack of landowner's cooperation	(percent)	4	18
Insufficient roughage-consuming livestock	(percent)	15	37

TABLE C-6. OPERATORS' CHARACTERISTICS AND OBSTACLES ON 20 FARMS WITH SOIL LOSSES BELOW THE SAMPLE MEAN AND WITH A TOPOGRAPHIC RATING OF 3 OR ABOVE, AND FOR ALL FIRMS IN A SAMPLE IN WESTERN IOWA, 1957.

Item	Units	Group mean	Sample mean
Soil loss per farm	(tons per acre)	8.6	14.1
Topographic rating per farm	(index number)	3.7	2.5
Soil conservation district participation			
Complete cooperator	(percent)	75	33
Initial cooperator	(percent)	15	17
Noncooperator	(percent)	10	50
Operator's estimate of seriousness of problem			
Major problem	(percent)	65	43
Somewhat of a problem	(percent)	30	34
No problem	(percent)	5	23
Days off-farm employment			
None	(percent)	45	65
1 to 159	(percent)	35	22
160 and over	(percent)	20	13
Operators with ability to borrow funds for erosion-control practices	(percent)	70	70
Acres farmed per operator	(acres)	252	214
Animal units per farm	(animal units)	34.0	33.2
Type of tenure			
Owner-operator	(percent)	45	49
Part-owner	(percent)	10	12
Tenant	(percent)	45	39
Operator's obstacles			
Need for immediate income	(percent)	40	51
Custom and failure to see need	(percent)	0	42
Rental arrangement and lack of landowner's cooperation	(percent)	10	18
Insufficient roughage-consuming livestock	(percent)	40	37

TABLE C-7. OWNERS' CHARACTERISTICS AND OBSTACLES ON SEVEN FARMS IN WESTERN IOWA WHERE OWNERS HAD NO EFFECTIVE OBSTACLES TO EROSION-CONTROL PRACTICES, 1957.

Item	Units	Group mean	Sample mean
Soil loss per farm	(tons per farm)	7.7	15.4
Topographic rating per farm	(index number)	2.8	2.4
Soil conservation district participation			
Complete cooperator	(percent)	0	31
Initial cooperator	(percent)	43	22
Noncooperator	(percent)	57	47
Owner's estimate of seriousness of problem			
Major problem	(percent)	29	26
Somewhat of a problem	(percent)	42	41
No problem	(percent)	29	33
Owners with ability to borrow funds for erosion-control practices	(percent)	57	88
Type of lease			
Cash-crop share	(percent)	71	53
Crop-livestock share	(percent)	29	33
Crop-share	(percent)	0	8
Cash	(percent)	0	6
Owner's obstacles			
Need for immediate income	(percent)	29	55
Insufficient roughage-consuming livestock	(percent)	0	31
Operator's obstacle of need for immediate income	(percent)	29	53
Additional acres owned per owner	(acres)	1,694	391
Owners over 65 years of age	(percent)	57	57

TABLE C-8. OWNERS' CHARACTERISTICS AND OBSTACLES ON SIX FARMS IN WESTERN IOWA WHERE SOIL LOSSES WERE BELOW 5 TONS PER ACRE IN 1957.

Item	Units	Group mean	Sample mean
Soil loss per farm	(tons per acre)	3.6	15.4
Topographic rating per farm	(index number)	1.7	2.4
Soil conservation district participation			
Complete cooperator	(percent)	34	31
Initial cooperator	(percent)	33	22
Noncooperator	(percent)	33	47
Owner's estimate of seriousness of problem			
Major problem	(percent)	17	26
Somewhat of a problem	(percent)	33	41
No problem	(percent)	50	33
Owners with ability to borrow funds for erosion-control practices	(percent)	50	88
Type of lease			
Cash-crop share	(percent)	83	53
Crop-livestock share	(percent)	17	33
Crop share	(percent)	0	8
Cash	(percent)	0	6
Owners' obstacles			
Need for immediate income	(percent)	50	55
Insufficient roughage-consuming livestock	(percent)	17	31
Operator's obstacle of need for immediate income	(percent)	33	53
Additional acres owned per owner	(acres)	228	391
Owners over 65 years of age	(percent)	83	57

TABLE C-9. OWNERS' CHARACTERISTICS AND OBSTACLES ON NINE FARMS WHERE SOIL LOSSES WERE LESS THAN 14.1 TONS PER ACRE AND TOPOGRAPHIC INDEX WAS 3 OR ABOVE IN 1957.

Item	Units	Group mean	Sample mean
Soil loss per farm	(tons per acre)	7.9	15.4
Topographic rating per farm	(index number)	3.4	2.4
Soil conservation district participation			
Complete cooperator	(percent)	11	31
Initial cooperator	(percent)	33	22
Noncooperator	(percent)	56	47
Owner's estimate of seriousness of problem			
Major problem	(percent)	56	26
Somewhat of a problem	(percent)	11	41
No problem	(percent)	33	33
Owners with ability to borrow funds for erosion-control practices	(percent)	67	88
Type of lease			
Cash-crop share	(percent)	45	53
Crop-livestock share	(percent)	55	33
Crop share	(percent)	0	8
Cash	(percent)	0	6
Owner's obstacles			
Need for immediate income	(percent)	11	55
Insufficient roughage-consuming livestock	(percent)	56	31
Operator's obstacle of need for immediate income	(percent)	22	53
Additional acres owned per owner	(acres)	702	391
Owners over 65 years of age	(percent)	66	57

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