THREE SELECTED QUESTIONS ON SOIL CONSERVATION

THREE SELECTED QUESTIONS ON SOIL CONSERVATION

By

VICTOR BRYANT PHILLIPS

Bachelor of Science

Langston University

Langston, Oklahoma

1942

Submitted to the faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1953

THREE SELECTED QUESTIONS ON SOIL CONSERVATION

Thesis Approved:

Robert L. Tonty
Chairman, Thesis Committee

Peter Nelson
Head of the Department

D. G. McIntosh
Dean of the Graduate School

ACKNOWLEDGMENTS

The author is grateful to the Department of Agricultural Economics, Oklahoma A. and M. College, for the honor of being granted a graduate assistantship (Project 449-A), which in part enabled the completion of this study, and for the encouragement and cooperation in preparation of this manuscript.

Special acknowledgments are tendered Dr. Robert L. Tontz, Assistant Professor of Agricultural Economics and thesis adviser, for his guidance, cooperation, and special interest in the study. Thanks are due to Mr. Leo Blakley, Assistant Professor of Agricultural Economics, for his kindness in reading this manuscript and for his worthwhile advice and suggestions.

Among the persons outside of the department to whom expressions of gratitude are extended for their services are Mr. J. H. Stallings, Research Specialist, United States Department of Agriculture, Agricultural Research Administration, Bureau of Plant Industry, Soils, and Agricultural Engineering, Beltsville, Maryland; Mr. H. H. Finnell, Research Specialist, Soil Conservation Service, Goodwell, Oklahoma; Mr. Harley A. Daniel, Project Supervisor, Soil Conservation Service, Guthrie, Oklahoma; Mr. W. Elmo Baumann, Soil Scientist in charge of laboratory, United States Department of Agriculture, Soil Conservation Service, Oklahoma A. and M. College; and Mr. Louis E. Derr, State Soil Scientist, United States Department of Agriculture, Soil Conservation Service, Oklahoma A. and M. College. I must also extend thanks to Miss Elizabeth J. Kerby for her stenographic service.

Finally, I must say thanks to my lovely wife, Alice Marie, for her loyal support and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

Purpose of Study

The objective of this study--suggested to the writer by the thesis adviser--is to provide information on three separate but related questions on soil conservation. The first question concerns the applicability of current definitions of soil conservation. The second and third inquiries relate to the extent of soil erosion and yield losses resulting from soil erosion.

Scope and Method of Procedure

In attempting to answer these questions, the writer undertook an extensive review of literature. The primary objective in reviewing completed research work was to study past and present information as an aid in determining the most desirable answers to the questions. A preliminary survey of available material was first made, however, to determine if any studies had already been made relative to the study undertaken. There was no evidence in this regard found by the writer.

A detailed survey of information was undertaken, beginning in June and continuing through December, 1952. As a preliminary preparation for the survey, the writer and thesis adviser formulated an investigating "key" designating the subject topics to be investigated. This was done to facilitate a relatively complete coverage of the data with a minimum of effort. After a preliminary effort the "key" was modified slightly and as used included the following subjects: agriculture, conservation, economics, erosion, land, production, soil conservation, soil erosion and yield. The subject topics mentioned above were used as the key to provide a systematic compilation of pertinent literature on the subjects under inquiry. The key was used on the following indexes: Agricultural Indexes from January 1916 to August 1952; The Public Affairs Information Service Indexes from July 1915 to September 1952; The Readers Guide to Periodical Literature from December 1890 to December 1952; The New York Times Index from September 1851 to December 1952; The Cumulative Book Index from January 1928 to November 1952; The Industrial Arts Index from May 1913 to August 1952; and the specialized Bibliography on Land Utilization, 1918-1936, compiled by Louis O. Bercaw and A. M. Hannay. The card catalog, the Encyclopaedia of Social Sciences, and the Oxford English Dictionary of the Oklahoma A. and M. College library were also investigated.

In addition to the sources already mentioned personal interviews and letters of inquiry were undertaken to get additional information.

After completion of the survey and compilation of the data, the writer undertook a study of the various items that had been compiled to determine the principal references for preliminary examination. The first inspection served as a basis in selecting the information that was to be used in this report. A further examination of the selected data was made to discard any information that would not be of value in this report.

CHAPTER II

HOW APPLICABLE ARE CURRENT DEFINITIONS OF SOIL CONSERVATION

In the past four decades the economics of soil conservation has been given attention by several prominent writers, among whom may be mentioned Charles R. Van Hise, Erich W. Zimmerman, L. C. Gray, Arthur C. Bunce, Rainer Schickele, Conrad H. Hammar, Earl O. Heady, and O. J. Scoville.

The objective of this chapter is to discuss the applicability of two definitions of soil conservation that are the outgrowth of extended work by three writers in agricultural economics. The definitions discussed are those by Arthur C. Bunce on the one hand, and Earl O. Heady and O. J. Scoville on the other. These writers--evolving their definitions in part from the experience of previous authors--recommend them for economic appraisals of conservation questions.

The applicability test is based upon the usability of the definitions in determining when a composite resource such as soil is conserved. As a background for judging the applicability, a review of definitions of conservation, soil conservation, and a definition of soil is undertaken.

Conservation Ideas and Definitions

In an approach to the full meaning of conservation, the concepts of principal thinkers in this and other fields will be reviewed. The term "conservation" apparently has different meanings for different people. Previous to the beginning of the twentieth century the term "conservation" was used mainly in the spiritual or moral sense, with a positive or negative implication, of keeping institutions, ideals, prerogatives, and the like unimpaired in the status quo.[1]

During the first quarter of the twentieth century terms like "maintenance," "improvement," and "just distribution," characterized some of the important concepts of conservation.[2]

So far as is known one of the first general and most distinguished conferences on conservation ever held was that called by President Theodore Roosevelt at the White House on May 13 to 15, 1908.[3] Of the over eight hundred delegates, more than one hundred read formal papers or took part in

---

[1]Siefried von Ciriacy-Wantrup, "Private Enterprise and Conservation," Journal of Farm Economics, XXIV (February, 1952), pp. 75-79.

[2]Arthur C. Bunce, Economics of Soil Conservation (New York, 1948), p. 1.

[3]Proceedings of Conference of Governors 1908 (Washington, D.C.).

the discussion.[1] The complete report fills a volume of 450 pages.[2] This group included the ablest and most mature leaders in conservation in the United States 45 years ago.[3]

In their papers and discussions, it appears that one should be able to find the best thought of that day as to the meaning of conservation, but in four days of speech making and deliberations there was no mention of the meaning of conservation. Without doubt the conference was called to dramatize a great present vital topic for the public; in this it appears to have succeeded. Reoccurring through all the papers are the words, "exhaustion," "waste," "destruction," "wise use," and "foresight."

President Roosevelt in the opening address of the conference points out that Americans have become great in a material sense because of the lavish use of resources, and that these resources used have made a great nation which citizens can be justly proud of.[4]

He also points out that the abundance of natural resources today may someday be gone, the forest bare, the coal, the iron, the oil and gas will have been exhausted,

---

[1] *Ibid.*, pp. 32-35.

[2] *Ibid.*, p. 35.

[3] *Ibid.*

[4] *Ibid.*, p. 8.

the soils will be further impoverished and washed into the streams.[1]

President Roosevelt, although aware of conservation, did not have clearly in mind all of the complex economic repercussions of a policy of conservation. He did, however, see that conservation involved foresight on the part of the present generation in the use and restriction of the use of natural resources for the welfare of future generations when he said "one distinguishing characteristic of really civilized men is foresight."[2]

President Roosevelt further suggested that leaders need to exercise foresight for the nation in the future, and if foresight is not exercised, dark will be the future. Foresight should be exercised now as the ordinary prudent man exercises foresight in conserving and wisely using the property which contains the assurance of well being for himself and his children.[3] In effect he considered conservation as synonymous with preserving more for future generations.

A few years later, President Van Hise of the University of Wisconsin, defined conservation as doing the greatest good to the greatest number and that for the longest time.[4]

---

[1] Ibid., p. 8.

[2] Ibid.

[3] Ibid.

[4] C. R. Van Hise, Conservation of Natural Resources in the United States (New York, 1910), p. 379.

This loose statement had little scientific value, as pointed out by Conrad H. Hammar who states that "conservation is not the greatest good to the greatest number, but the highest average good to a moderate number that is sought."[1]

As early as 1913 Gray regarded the heart of the conservation problem as being economic in nature with the observation that "conservation is the determination of the proper rate of discount on the future with respect to the utilization of our natural resources."[2] The basic problem of conservation, as Gray points out, is the determination of the proper rate of discount for the future; in this respect it is the same as the problem of investment and is essentially economic in nature.

Richard T. Ely suggests that conservation means three things. They are (1) maintenance as far as possible, (2) improvement where possible; and (3) justice in distribution.[3] Regarding the latter point he states that "conservationists wish to cut off, or at least reduce, the private receipt of property and income beyond what is a fair return to capital and labor and enterprise, reserving the surplus

---

[1]Conrad H. Hammar, "Economic Aspects of Conservation," Journal of Land and Public Utility Economics (1931), p. 282.

[2]L. C. Gray, "Economic Possibilities of Conservation," Quarterly Journal of Economics, Vol. XXVII (1913), p. 499.

[3]Richard T. Ely in The Foundations of National Prosperity by Ely, Hess, Leith and Carver (New York, 1918), p. 6.

for public use."[1] Ely appears to give no explanation of what is a fair return to capital and labor, and how the surplus reserved for public use is derived.

A more recent definition of conservation is that stated by Aldo Leopold, "conservation means harmony between men and land."[2] He points out that this comes about by land doing well for its owner, and the owner doing well for his land. When both land and owner end up better by reason of their partnership, the nation has conservation, but when one or the other grows poorer it is not conservation.[3]

It appears that the above definition is largely limited to the farmer and his farm. It perhaps falls in the field of biological forces. It is not primarily concerned with the inanimate universe, metals and minerals. It states the position of the ecologist and that for a phase of conservation is important. This definition is more of a statement of purpose, or ends to be attained, or a philosophy of life than a definition of conservation as such.

Zimmerman states that conservation involves a reduction of the rate of disappearance or consumption and a

---

[1] Ibid., p. 6.

[2] Aldo Leopold, "The Farmer As A Conservationist," American Forest (June, 1939), p. 295.

[3] Ibid.

corresponding increase in the unused surplus left at the end of a given period.[1]

He also points out that the conscious interference with the free play of economic forces with the avowed purpose of helping posterity even at the expense of the present generation of producers and consumers is called conservation.[2]

Broadly interpreted, conservation includes a set of principles that deal with every activity and every resource that affect public and private welfare. Thus, in using the term conservation, it is essential that its scope be defined and the particular resources to which it applies be designated; otherwise, its meaning is so broad that it has little significance.[3] Erich W. Zimmerman concludes that "the word conservation seems impossible of final definition, for its meaning changes with time and place."[4]

Definitions of Soil Conservation

The term, "soil conservation," has different meanings among the leading conservation students.

---

[1]Erich W. Zimmerman, World Resources and Industries (New York, 1951), p. 806.

[2]Ibid.

[3]A. F. Gustafson and W. J. Hamilton, Conservation in the United States (New York, 1949), p. 3.

[4]Zimmerman, op. cit., p. 804.

According to the following professors of Cornell University, Gustafson, Guise, and Hamilton, "conservation is an economic and social problem, it is not primarily one of sentiment."[1]

According to Weitzell's thesis, Economics of Soil Con-Servation in West Virginia, "soil conservation is the continuous utilization of land in a manner that will maintain an economic level of productivity in perpetuity."[2] With this analysis of soil conservation, he points out the necessity of maintaining the soil fertility while using the land continuously.

Collier expresses soil conservation as a goal in which one achieves better land use and relatively permanent systems of farming, to provide a better life for people living on the land, and to insure protection of public welfare.[3]

The Northwest Regional Council explains that soil conservation implies wise use and care of the land, in such a way that it will retain its natural fertility of productivity.[4]

---

[1]A. F. Gustafson, C. Guise, and W. J. Hamilton, Conservation in the United States (New York, 1949), p. 18.

[2]Everett C. Weitzell, Economics of Soil Conservation in West Virginia, p. 209.

[3]George W. Collier, "Soil Conservation Service," Journal of Farm Economics, Vol. 24, (February, 1942), p. 124.

[4]Northwest Regional Council, "The Meaning of Soil Conservation," Soil Conservation Outline, (June, 1940), p. 6.

According to the above definition of soil conservation it appears to mean using the land to produce the greatest amount of the things best adapted to the land, and at the same time protecting it so that it will not lose its productiveness.

H. H. Bennett, former Chief of the Soil Conservation Service of the United States Department of Agriculture, states that soil conservation is the use of land, within the limits of economic practicability, according to its capabilities (the way nature made the land) and its needs (as affected by man's use of the land) in order to keep it permanently productive.[1] He further expresses in agronomic explanation more specifically that soil conservation consists of safeguarding all kinds of useful land, as nearly all kinds of land are useful for some purpose. On the other hand, soil conservation is safeguarding or preventing the depletion caused by the following: (1) excessive soil removal; (2) deposition of the products of erosion; (3) accumulation of toxic salts; (4) burning the field; (5) exhuastion of plant nutrients through leaching, excessive cropping, and overgrazing; (6) inadequate drainage, in case of water logging; and improper cultivation, or failure to protect the land from soil loss.[2]

---

[1]H. H. Bennett, Elements of Soil Conservation (New York, 1947), p. 128.

[2]*Ibid.*, p. 128.

Robert H. Shields, former Administrator of Production and Marketing Administration, suggests that soil conservation means maintaining of abundant production of food and fiber both now, and in the years to come.[1]

According to a recent publication of the Soil Conservation Service, soil conservation means a permanent, profitable agriculture by using the right combination of conservation practices.[2]

Soil conservation has been defined as common sense farming with scientific methods. It involves (1) sound land use; (2) the right combination of conservation practices; (3) maintenance and improvement of soil productivity; and (4) economically sound conservation farming.[3]

As reported by the Oklahoma Conservation Committee, the ultimate objective of soil conservation is the maintenance of permanent productivity of land as far as possible.[4]

---

[1]Robert H. Shields, "Soil Conservation Practice Payment," Report of the Administrator of the Production and Marketing Administration (1946), p. 8.

[2]United States Department of Agriculture, "No One Can Afford Erosion," Soil Conservation Service, (August, 1947), p. 3.

[3]United States Department of Agriculture, "Erosion Can Be Controlled," Soil Conservation Service, (August, 1947), p. 3.

[4]State Soil Conservation Committee, "History of Soil Conservation," Biennial Report, Oklahoma, December, 1952, p. 1.

More recent definitions of soil conservation are those of Arthur C. Bunce and Earl O. Heady and O. J. Scoville.

Soil Conservation as discussed by Bunce applies to agricultural land, or more particularly to the soil resources of agriculture.[1] Arthur C. Bunce, assistant professor of agricultural economics, Iowa State College, states that agricultural soil resources partake of several characteristics compositely, which make it necessary to explain how conservation can be had when a composite of different qualities or properties are under consideration.[2]

He further points out that soil has the characteristics of fund resources which are limited in amount, and conservation may be defined as a reduction in the rate of consumption which will leave a larger quantity available for future use.[3] Another of the qualities of the soil is that it is a "flow resource" and is described by Bunce as occurring periodically over time, and conservation means using such resources in such a way that physical waste (non-use) is minimized.[4] Then a final classification used by Bunce is that of "biological resources" that partake of the characteristics of both fund and flow resources, a composite quality, and conservation may

---

[1]Bunce, op. cit., p. 4.

[2]Ibid.

[3]Ibid.

[4]Ibid., p. 5.

be defined as the maintenance of the present level of productivity.[1]

Because of the difficulties associated with formulating a definition of conservation respecting agricultural land, Bunce suggests it be wise to restrict the meaning of the term to the physical sense, and use the adjective "economic" or "uneconomic" to imply monetary measures.[2] Any formulation of a definition of conservation would in this case be in agreement with the physical one set forth by Bunce when he says "conservation of agricultural land appears to mean the maintenance of the fund resources and the present level of productivity of the soil, assuming a given state of the arts."[3]

Heady and Scoville state that soil conservation is the prevention of diminution in 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.)[4]

Since soil is a composite of fund and flow resources and conservation has many meanings, it seems impossible for any

---

[1] Ibid.

[2] Ibid., p. 4.

[3] Ibid., p. 7.

[4] Earl O. Heady and O. J. Scoville, "Principles of Conservation Economics and Policy," Research Bulletin No. 382, Ames, Iowa (July, 1951), p. 375.

one of the aforementioned definitions to be entirely applicable in every instance.

Characteristics and Nature of Soil

An understanding of the rightful meaning or definition of "soil" must be had in order to fully test the applicability of recent analytical definitions of soil conservation. In deriving a usable definition of soil it may be well to review the concepts of the soil scientist or soil pedologist.

Hilgard states that soil is the more or less loose and friable material in which, by means of their roots, plants may or do find a foothold and nourishment, as well as other conditions of growth.[1]

Firman E. Bear, professor of soils, Ohio State University, writes that soil is the residue left behind in the disintegration and decomposition of rocks, mixed with varying amounts of plant and animal refuse.[2]

Burges points out that soil is the thin layer of finely broken rock material and decaying organic matter which covers

---

[1]E. W. Hilgard, Soils, Their Formation, Properties, Composition and Relation to Climate and Plant Growth (New York, 1911), p. 23.

[2]Firman E. Bear, Soil Management, (New York, 1924), p. 26.

most of the earth and furnishes a medium of growth for plants.[1]

Byers, Kellogg, Anderson and Thorp state in their study of formation of soils that the soil is a mixture of fragmental rocks and minerals, organic matter, water, and air, in greatly varying proportions and have more or less distinct layers of horizons developed under the influence of climate and having organisms.[2]

They further point out that soils are dynamic in character, they are constantly undergoing change but they normally reach a state of near equilibrium with their environment, and after a long period of exposure to given set of conditions they may change but little during periods of hundreds or even thousands of years unless there is a change in the environment.[3]

Hans Jenny states that soils are those portions of the solid crust of the earth, the properties of which vary with soil-forming factors, climate, organisms, topography, parent material and time.[4] According to this definition soil consists of a layer of unconsolidated materials at the earth's

---

[1]Austin Earle Burges, Soil Erosion Control (Atlanta, Georgia, 1936), p.33.

[2]United States Department of Agriculture, Soil and Men Yearbook of Agriculture, 1938, p. 948.

[3]Ibid., p. 948.

[4]Hans Jenny, Factors of Soil Formation (New York, 1941), p. 17.

surface, which has been derived from rock and organic matter through agencies of decay and disintegration.

Wilbert Wier, soil technologist formerly of the Bureau of Chemistry and Soils, United States Department of Agriculture, in his concept of soil suggests that when any earthy body was classified as soil, it contained certain attributes that are common to all soils in the world, and a careful analysis of this classifying process, in accord with the modern concept of soils will show three principal common elements which are distinguishing characteristics, such as color, layers, and structure that have developed to a greater or lesser degree as the result of the action of specific natural forces. The soil body has an inherent nature that shows not only the origin of soils from loose geologic material, but also their filial relation to the loose geological substratum material immediately below them and the ability to support the growth of plants.[1]

According to this meaning, soils are earthy bodies on which distinguishing characteristics have developed as the result of the action of specific natural forces on the accumulated residue that results from rock weathering, whose earthy bodies constitute the upper part of the outer unconsolidated layer of the earth's crust, and in which soil plants grow.

---

[1]Wilbert Walter Weir, Soil Science, Its Principles and Practices (New York, 1949), p. 142.

According to a more recent study, Bunce states that soil has the characteristics of "fund resources" which are limited in amount, "flow resources" occurring periodically over time, as for example water flow, sunshine and fertility from the actions of solutions and organisms in the soil together with fibre or organic matter formed by the growth of roots and the spacial elements of land and the "biological resources" that partake of the characteristics of both fund and flow resources, a composite quality.[1]

Sigmond suggests that most pedologists still insist on briefly defining soil as the outer weathered layer of the solid earth's crust.[2] He points out, however, that in the light of our present pedological knowledge this definition is inadequate.[3] Sigmond further observes that the soil is certainly the outer layer of the solid earth in contact with the air and more or less weathered, but he indicates further that this is not all that can be said about soil, because rocks are regarded as the symbols of stability and solidity, the soil is the soft bed of seeds and plant roots, the support and food of the vegetable world and the home of change. Rocks are dead mineral substances, while the soil teems with life and is the source of all new vegetation.[4]

---

[1]Bunce, op. cit., pp. 4-6.

[2]Alexius A. J. de Sigmond, The Principles of Soil Science (London, 1938), p. 3.

[3]Ibid., p. 3.

[4]Ibid.

One of the outstanding properties of the soil is that it may become the carrier of higher vegetation. It is in the soil that inorganic substances are transformed into living organisms, and dead organic matter also changes back into inorganic compounds.[1]

Burges in a summary of the meaning of soil suggests that it is the heritage of the human race, the product of disintegrated rock compounded with the organic remains of all previous life. It is the cradle of the seed, the support and sustenance of the growing grain, the last resting place of the fallen plant. It is nature's marvelous laboratory wherein the inert remains of plants and animals are broken down into their component parts and again infused into living things.[2]

He further states that soil is incredibly slow to form but swift as the dashing rains to erode. Once wasted, it can never be exactly re-formed as before nor feasibly replaced by man.[3]

Sigmond concludes that soil is the scene of constant changes and transformation, a dynamic system in contrast to the static system represented by rocks, and minerals.[4]

---

[1] Ibid.

[2] Burges, op. cit., p. 1.

[3] Ibid.

[4] Sigmond, op. cit., p. 5.

It is problematic whether any definition of soil could be formulated to which everyone would agree or to which all situations could be applied.

In order to more clearly present and discuss the applicability of recent analytical definitions of soil conservation, and to help the reader determine when "soil" is or is not being conserved, it is necessary that the writer explain the term "soil."

The term "soil," as used in this study, designates the sur-ficial portion of the earth, the layer extending from the surface down to some decided change in the texture, color, or structure of the material, a composite resource containing fund resources, flow resources, and biological resources, it may be only a few inches deep, or it may be a foot or more. This portion is frequently referred to as surface soil.

Test of Application of Two Current Definitions of Soil Conservation

This section of Chapter II is a discussion of the applicability of two current definitions of soil conservation. The first is that of Arthur C. Bunce, and the second is the combined product of Earl O. Heady and O. J. Scoville. These writers have devoted considerable research time and thought to the field of conservation and offer their definitions for economic appraisals of conservation questions.

In his writings Bunce emphasizes that "soil conservation is the maintenance of the fund resources and the present level of productivity of the soil, assuming a given state of the arts."[1]

Heady and Scoville define soil conservation as "the prevention of diminution in 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)."[2]

In testing the applicability of these definitions of soil conservation, the term "soil" will be referred to in this discussion as the sur-ficial portion of the earth, or the layer extending from the surface down to some decided change in the texture, color, or structure of the material, a composite resource containing fund resources, flow resources, and biological resources; it may be only a few inches deep, or it may be a foot or more in depth; this portion being frequently referred to as surface soil.

In order to appraise the applicability of Bunce's definition of soil conservation, it seems appropriate to divide it into two parts. First, he states that the "fund" resources must be maintained, assuming a given state of the arts. The meaning of fund resource refers to the limited

---

[1]Bunce, *op. cit.*, p. 7.

[2]Heady and Scoville, *op. cit.*, p. 375.

inanimated body of the soil. Then, in order to maintain the fund resource there must be a holding or keeping of the soil body in its particular state, assuming that there is no change in the state of the arts. Bunce observes in the second part of the definition that the present level of productivity of the soil must be maintained, assuming a given state of the arts. This seems to indicate that the ability of the soil to produce must be kept in a particular state for given technological conditions.

In applying this definition of soil conservation and putting it into use, a consideration of the feasibility and use of a definition which is to be applied to a composite of fund and flow resources must be given. Can both fund and flow resources be maintained when the fund resources are limited in amount and are irreversible in character, and the flow resources occur periodically over time and may be replaced? To maintain the fund resource would necessitate that the inanimate soil body be kept in its present state permanently, undiminished and unimpaired. The conservation of fund resources in the sense of maintaining or keeping the resource permanently undiminished and unimpaired is clearly spurious. If conservation were understood in this sense, soil formation and soil deterioration would have to remain zero. Productivity is greatly affected by flow resources, and flow resources which occur periodically over time are influenced by uncontrollable phenomena. Since soil is a composite of both fund and flow resources, it appears that conservation should refer specifically to maintenance of the fund resource in its natural formation, but could permit temporary changes in the flow resources. What evidence is there to indicate that the present level of soil productivity is currently being maintained? Is there not also increased productivity through current conservation efforts?

While it has the great merit of calling attention in a very few words to the most important general characteristics (maintenance of the fund resources) involved, a definition of this sort is so lacking in precision on certain particular points that it leaves the way open for rather serious misunderstandings. First, it is not clear whether the effects of cost and price are excluded or not by the proviso that the state of the arts remain unchanged. It is not clear what the state of the arts include, and can they be agreed upon by any two people? Second, it is uncertain whether the fund resources and the flow resources can be maintained. And third, nothing is said as to whether or not this definition is to be applied physically or economically.

Largely because of this last deficiency, this definition fails to bring out as it should the symmetrical character of the inter-relationship of factors involved. The Bunce definition of soil conservation is not incorrect, but it is neither sufficiently precise nor sufficiently complete to afford an adequate foundation for the analysis that necessarily must be based upon it.

Although the most important consequence of this definition is that within certain limits fund resources and flow resources may be maintained, it is nevertheless more helpful for general analytical purposes to formulate a definition in terms of physical and economic understanding, rather than only in terms of either physical or economic meaning.

Heady and Scoville suggest that soil conservation is the prevention of decrease in forthcoming 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). In the opinion of the writer, this definition appears to be only partially applicable to the physical aspects of soil conservation if one accepts its basic assumptions; however, how likely is he to find a period long enough in which to measure the effects of conservation with a given state of the arts? How reasonable is it to assume that production technique, new inventions, improved varieties of seed, and climatic conditions are to remain fixed?

What an inquiry into the problem of defining soil conservation is most likely to find is a change in production due to all these above variables. Then arises the problem of allocating the increase or decrease in production between the factors causing the change to be forthcoming. Theoretically, this allocation would be possible, for one can hold all the variables constant except one; calculating the change in production, such change will be due to the variable factor. Empirically one does not have enough information.

Although both definitions discussed above are somewhat inadequate, the difficulties of interpretation arise more from omissions than from restrictions stipulated. A more conclusive definition could be reached by determination of definite, positive, clear descriptions in order to clarify the basic definitions. How can one ever measure conservation or apply a static definition to a dynamic society? Does one have enough information for each of the soil factors to tell how much is soil conservation and how much is something else? How important is soil conservation as long as there is a dynamic society?

If it is conceived that the definitions of soil conservation as mentioned above are acceptable in terms of physical inputs and outputs, both society as a whole and individual farmers are faced with a further problem, whether the practice involved to maintain a present level is profitable; whether physical inputs relative to output would be profitable now or in the long run.

The future of technology and the economy may not allow the present level to be productive. What would be the present outcome of the conservation of the draft horse initiated in the 1930's? Certain soil in agricultural use may go out of production and others may come in; it may be better to let certain land go. Why should one hold a man by subsidizing land? In agriculture no one problem (biological, e.g. seed improvement; physical, e.g. soil; and economic, e.g. changes in wants; income status and freely expressed price) has been the adaptation. Quality may be a problem some day as well as quantity.

To adhere rigidly to either definition, especially to do so to the point of public subsidy would tend to hamper the freedom of adjustment of changing conditions.

The writer also believes worthy of consideration the economic implications. The economic use of soil involves not only the question of maintenance, but also of exploitation and improvement. The general statement that the soil must be conserved has little meaning when applied to all soil groups. In many cases the needs exist not only to conserve the soils, but also to improve or even, in some instances, to exploit them. Especially is this true of the flow resources. Conservation that would try to hold agricultural productivity of a virgin soil with distant markets at the original level may be wasteful or uneconomic, and therefore exploitation may be economic for the individual. Maintenance of the present level of productivity is a highly misleading statement, for conservation of the flow resources is economically meaningful only if its use is considered.

The economic implications may be expressed in a simple form in terms of marginal theory under the assumptions of a flexible competitive economy. Exploitation that results in soil deterioration represents erosion and fertility losses which permanently lower the value of the land; this occurs when the cost of restoring the physical productivity of the soil after a period of exploitation would be greater than the sum of the annual cost, including interest, which would be incurred in maintaining it. Exploitation that results only in "fertility depletion," on the other hand, represents the use of resources that can be replaced later at a cost equal to or less than the cost of maintaining them. In the case of fertility depletion,[1] the productivity of the soil should be maintained at the point where the cost of marginal inputs equal the value of the marginal product. In the case of deterioration, exploitation would only be economic for the individual up to the point where the marginal returns from disinvestment equalled the value of the resource destroyed. Land improvement on the other hand involves capital investment, and it is economic for an individual to improve his land up to a point where the marginal returns from investment equal marginal cost. Up to this point the value of the improvement will be greater than the cost.

---

[1]Fertility depletion refers to the removal of plant nutrients from the soil, and occurs concurrently with erosion; a reduction in the productivity of the land may be the results of either one of these factors or both together. Bunce, op. cit., p. 14.

Bunce states that economically, conservation (capital maintenance) is essentially an equilibrium concept and is economic for the individual when further investment or disinvestment is uneconomic. At this point marginal returns from investment equal marginal cost, and marginal returns from disinvestment equal the value of the resources used up.[1]

---

[1] *Ibid.*, pp. 9-16.

CHAPTER III

EXTENT OF SOIL EROSION

Many writers on soil erosion and soil conservation, of whom may be mentioned, H. H. Bennett, M. E. Bear, Maxwell S. Stewart, J. V. Jacks, Karl B. Mickey, Russell Lord, Quincy Claude Ayres, Edward H. Faulkner and W. C. Bagley, suggested that soil erosion is causing a great loss of topsoil throughout the United States.

Professor Roland R. Renne, President of Montana State College, in his book, Land Economics, points out that in the United States approximately half (973,000,000 acres) of the land area of 1,903,000,000 acres is physically suited for crop production. Of the rest, 468,000,000 acres are arid grazing lands unsuited for any other purpose. Land in forests, fit only for forestry with incidental grazing, comprises an area of 262,000,000 acres, while some 66,000,000 acres not at present in forest is fit for pasture or forest, but not for crops. Some 67,000,000 acres are waste land (chiefly desert and rock) unfitted for crops, grazing and forests. The remainder of about 67,000,000 acres will be used in part for cities, towns, homesteads, recreation and other purposes.[1] About 80 percent of the cultivatible land is subject to erosion if not protected.

The writer did not attempt to record all of the studies on the extent of soil erosion because of the similarity of the data. It is the purpose of this chapter to show a few selected studies which indicate the general pattern of studies on the extent of soil erosion.

As a background for clarity of understanding the findings of the extent of soil erosion, a brief review of definitions of geological erosion and soil erosion is presented.

Definitions of Geological Erosion

Erosion is a natural process which has been sculpturing the face of the earth since the first winds began to blow and the first rains to fall. As a geological process erosion is a result of the impact of climatic forces such as rainfall, frost, and wind upon the land under varying conditions of slope and cover of natural vegetation; it is the wearing away of the land surface by running water, wind, waves and moving ice.[2]

Geological erosion assisted by the process of rock weathering aids both in the formation of soil and in its

---

[1]Roland R. Renne, Land Economics, (New York, 1947), p. 240.

[2]H. H. Bennett, Soil Conservation, (New York, 1939), pp. 92-93.

distribution from place to place. It occurs in a natural, undistributed environment when vegetation with its canopy, stems, ground cover of vegetative litter and underground network of binding roots together with the absorptive, stable character of humus-bound soil retards the transportation of surface soil by rain, wind and gravitational movements to a pace no more rapid, generally, than the pace at which new soil is formed from the parent material beneath.[1]

Russell Lord, an American writer, states that geological erosion, or natural erosion as it is sometimes called, is the gnawing away at naked rock. The weathering agencies--water and air, heat and cold, roots, worms, molds, bacteria, and the remains of all things living--combine to tear apart its massive substances and to distribute the particles; depositing here and there on land a thin and shifting film of rotted rock with the essence of life's renewal in it called soil.[2] He points out that erosion is a soil maker; but the timeless whips of wind and water let no land be at peace. Flicking and smashing at the landscape, the weather works to remove it, particle by particle, and to re-deposit it in new designs and formations, without regard for national or state lines, property rights, or the general welfare.[3]

---

[1] Ibid., p. 92.

[2] Russell Lord, Behold Our Land (Boston, Mass., 1938), p. 13.

[3] Ibid.

Arthur Holmes, professor of geology and mineralogy, of the University of Edinburgh, states that "geological erosion is the destructive process due to the effects of the transporting agents (wind, rain, rivers and glaciers) of nature."[1]

William J. Miller, professor of geology, University of California, suggests that the term "geological erosion" comprises all the processes whereby the lands are worn down.[2] He points out more specifically that it involves the breaking up, decay, and transportation of materials at and near the earth's surface by "weathering"[3] and "solution,"[4] and by the mechanical actions of running water, waves, moving ice, or winds which use rock fragments as tools.[5]

Based on a study of definitions of geological erosion, it appears that geological erosion is nature's system of production, distribution, and consumption of soil resources.

---

[1]Arthur Holmes, Principles of Physical Geology (New York, 1945), p. 24.

[2]William J. Miller, An Introduction to Physical Geology (New York, 1941), p. 106.

[3]"Weathering" comprises all processes, such as mechanical action of temperature changes, freezing of water, organisms, rain water and lightning, and the chemical action of atmospheric gases, water, and organisms, whereby rocks at and near the earth's surface break up, decay, or crumble. See William J. Miller, An Introduction to Physical Geology (New York, 1941), p. 81.

[4]"Solution" is the simple process of dissolving rock material, mainly by water. See William J. Miller, An Introduction to Physical Geology (New York, 1941), p. 107.

[5]Ibid., p. 106.

The production of soil is brought about by the breaking down of rock through the process of mechanical action, temperature changes, freezing of water, organisms, rain, water, lightning, and the chemical action of atmospheric gases, water and organisms. The distribution of soil (products) formation, is a process which removes the weathered rock fragments from the places of their origin. Specifically, these include the picking up of loose material and its transportation, including the agencies of rain, wind, moving ice, rivers, and streams. The consumption or solution of soil formation is carried on by the process of dissolving rock material, mainly by water and chemical action.

The relationship of geological erosion to soil erosion is the difference in the rate of denudation (L. denudo, to make bare) that would normally take place and the denudation caused by the actions of man.

Definitions of Soil Erosion

The term "soil erosion" has different meanings among the leading soil conservationists and land economists.

For example, H. H. Bennett states "soil erosion is the vastly accelerated process of soil removal brought about by human interference with the normal equilibrium between soil building and soil removal."[1] If one may judge his thought from what he said Bennett appears to mean that normal

---

[1]Bennett, op. cit., p. 94.

equilibrium between soil building and soil removal is when soil is formed as fast as it is displaced bodily.

Other writers indicate that soil erosion may be defined as the wearing away of the soil, as the result of human practices faster than it is replaced by natural processes.[1]

G. V. Jacks, American writer and editor, and R. O. White, author and writer, refer to soil erosion as being an important symptom of bad relationship between people and the soil, just as a headache is often a symptom of some more fundamental illness.[2] Jacks and White further point out that soil erosion may be divided into two general classifications, vertical and lateral.[3] Vertical erosion is the leaching of the soluble soil nutrients down into the subterranean water tables, and occurs mostly in humid regions. Lateral erosion either washes or blows away the insoluble parts of the soil. The washing usually occurs in humid regions and the blowing in arid and semi-arid regions.

This study is concerned with lateral erosion, which consists of water erosion and wind erosion.

Bennett states that water erosion is the transportation of soil by rain water, including melted snow, running rapidly over exposed surface, and that it is conditioned by factors

---

[1]G. V. Jacks and R. O. Whyte, Vanishing Lands (New York, 1938), pp. 1-25.

[2]Ibid., pp. 1-25.

[3]Ibid., pp. 101-104.

of slope, soil type, land use and amount and intensity of rainfall.[1] Bennett also points out that water erosion may be divided into three stages: sheet erosion, rill erosion and gully erosion, and that actually there is no line of demarcation between the stages.[2]

Sheet erosion is an insidious wasting away of the soil; sheet erosion is the more or less even removal of soil in thin layers over an entire segment of sloping land.[3]

Rill erosion is characterized by small but well-defined incisions left in the land surface by the cutting action of the water, and instead of flowing evenly over a sloping field, runoff water tends to concentrate in streamlets of sufficient volume and velocity to generate increased cutting power.[4]

Gully erosion takes place either where the concentrated runoff from a slope increases sufficiently in volume and velocity to cut deep incisions into the land surface or where the concentrated water continues cutting the same groove long enough to develop such incisions.[5] Wind erosion is the transportation of soil by the forces of the wind.[6]

---

[1]Bennett, _op. cit._, pp. 95-96.

[2]_Ibid._, pp. 96-100.

[3]_Ibid._, pp. 100-102.

[4]_Ibid._, pp. 102-109.

[5]_Ibid._, p. 102.

[6]_Ibid._, p. 116.

Austin E. Burges, popular writer of Dallas, Texas, points out that soil erosion is the removal of soil by natural agencies, of which water and wind are the most active.[1]

Arthur C. Bunce, formerly assistant professor of agricultural economics, Iowa State College, states that soil erosion is the result of the activities of man, which include wind erosion, and water erosion. The term "erosion" generally implies a movement of the soil; it may be extremely rapid or very slow and represents a destruction of the fund resources of the soil.[2]

The fund resource is the inanimate body of soil particles and is limited in amount.

Professor Schiekele, formerly of Iowa State College, writes that erosion is the most conspicuous form of soil deterioration and, from an economic viewpoint, also the most dangerous because of its "irreversible"[3] character.[4]

---

[1]Austin Earle Burges, Soil Erosion Control (Atlanta, Georgia, 1936), p. 1.

[2]Arthur C. Bunce, Economics of Soil Conservation (Iowa, 1948), p. 14.

[3]Once the fertile topsoil is washed away and the land is dissected by numerous gullies, it is extremely difficult and often impossible to restore a profitable level of productiveness.

[4]Rainer Schickele, Economics of Agricultural Land Use Adjustments. I Methodology in Soil Conservation and Agricultural Adjustment Research, Research Bulletin 209, Iowa Agricultural Experiment Station (March, 1937), p. 363.

Bunce points of that disinvestment (or exploitation that results in soil deterioration) represents soil erosion and fertility losses which permanently lower rent; the lowering of rent, soil deterioration or exploitation occur when the cost of restoring the physical productivity of the soil after a period of exploitation would be greater than the sum of the annual costs, including interest, which would be included in maintaining it.[1]

Deterioration or erosion implies a loss in the value of the soil as productive capital resulting from impairment of its physical properties, and means permanently lower rent to the owner or higher prices to the consumer.[2]

After a study of definitions of soil erosion it may be concluded that soil erosion represents an accelerated process of denudation and destruction of the fund resource or the inanimate soil body effected by man, beyond that which is caused by natural or geological erosion.

Area Affected by Soil Erosion

When the first settlers came to the United States they found the land covered with a dense vegetative growth of native grasses on the open prairie, and timber, brush, and

---

[1]Bunce, op. cit., p. 14.

[2]*Ibid.*, p. 14.

grasses on the more hilly land.[1] H. H. Bennett states that during the early settlement vegetative cover held the rain and snow, and thus prevented the loss of water by runoff during the heaviest rains.[2] The precipitation was largely and rapidly absorbed by the soil because of its unusually high organic matter content which had been built up by the accumulation of grass roots and leaves through the ages. Even when the runoff did occur, the native vegetation protected the soil from being eroded or washed away.[3] If one accepts this as true then why did the Indians name some of the rivers as they did? (i.e. the Red River)

As the land was broken out of native sod and cultivated, native vegetative cover was destroyed and soil erosion began and nature's chief defense against this destructive action was broken down. Inter-tilled crops such as corn and cotton were grown, and the soil was left bare and exposed to soil erosion. The furrows left between corn rows served as channels for the collection and runoff of excess rain, these frequently developed into small gullies during single rains. In these water channels enormous amounts of the surface soil were carried away from much of the rolling land.[4]

---

[1] Bennett, op. cit., p. 1.

[2] Ibid.

[3] Ibid.

[4] Ibid.

As the land was more intensively cropped without regard to the maintenance of fertility, the organic matter content gradually decreased, and, as a result, the water absorption capacity was reduced. This increased the runoff water, which carried away more and more soil, and as the land became less and less productive owing to the loss of the fertile topsoil by erosion, new land was broken up and a continuing process of soil erosion took place.[1]

During World War I, increasing demands for food in Europe made it apparent that food production must be increased. The boom encouraged the breaking of virgin land and its utmost exploitation while the going was good. Probably more soil was lost from the world between 1914 and 1934 than in the whole of previous human history.[2]

This was particularly true of the plains sections of Oklahoma, Texas, Colorado, Kansas, and Nebraska where great stretches of plains were plowed and sowed to wheat.[3]

One duster alone--that of May 11, 1934--carried away an estimated 300 million tons of topsoil of western Kansas and Oklahoma and the bordering parts of Texas, Colorado, and Nebraska.[4] On the basis of 1,000 tons of topsoil covering

---

[1] Ibid., p. 2.

[2] Jacks and Whyte, op. cit., p. 220.

[3] Ibid.

[4] Karl B. Mickey, Man and the Soil (Chicago, 1945), p. 29.

one acre seven inches deep, that meant the equivalent of 3,000 one-hundred-acre farms taken out of crop production, if it be assumed these farms had only seven inches of topsoil to begin with. Consequently, when rain did come, whatever loose, dry soil that remained was subject to washing, leaving gullied sections of the land less productive than before.[1] Mickey asserts that soil erosion has taken 300,000 acres of farm land out of crop production. This is less than one percent of the land area of Oklahoma.

Professor F. L. Underwood, formerly of Virginia Polytechnic Institute and now associate professor of agricultural economics of Oklahoma A. and M. College, states in a study of flue-cured tobacco farm management that practically all of the tobacco area of Pittsylvania County, Virginia, showed evidence of erosion in 1933, but in general the degree of erosion on the tobacco area was less severe than for the farms as a whole. He further states, however, that about one-half of the tobacco acreage was eroded to the extent of the removal of 25 to 75 percent of the topsoil and only 3.3 percent was planted on land with more than 75 percent of the topsoil so removed.[2]

---

[1] Ibid.

[2] F. L. Underwood, Flue-cured Tobacco Farm Management, Technical Bulletin No. 64 (January, 1939), Virginia Polytechnic Institute, Virginia Agricultural Experiment Station, p. 12.

In a recent survey, the United States Soil Conservation Service claims that more than 50 million acres of former cropland had been seriously damaged, and still another 100 million acres had lost half or more of the original fertile topsoil as a result of soil erosion.[1] Donald C. Blaisdell in a report states that erosion has taken at least 37 percent of the topsoil of the total land area of the United States, which is about 1,900,000,000 acres.[2]

At present there are 415 million acres used for crops, of which at least 73 million acres are said to be too steep, too severely eroded or otherwise unsuitable for cultivation.[3] There is also a limited amount, perhaps 70 million acres of undeveloped land, but it must be cleared, drained, or irrigated before it can be placed in production.[4]

The calculation of the amount of soil removed by water and wind erosion annually in the United States, according to Edmund Worthen, professor of soil technology of Cornell University, indicates a total of about 3,000,000,000 tons.[5]

---

[1]R. D. Hockensmith, "The Need for an Inventory," Classifying Land for Conservation Farming, Farmers Bulletin No. 1853 (February, 1943), pp. 1-2.

[2]Donald C. Blaisdell, Government and Agriculture (New York, 1940), p. 100.

[3]R. D. Hockensmith, op. cit., p. 2.

[4]Edmund L. Worthen, Farm Soils, Their Management and Fertilization (New York, 1948), p. 166.

[5]Ibid.

The Mississippi River alone deposits annually some 700,000,000 tons of soil material in the Gulf of Mexico.[1] What proportion of eroded material is made up of topsoil cannot be accurately determined. It is known, however, that each year millions of tons of topsoil, much of which has a high content or organic material, is lost from the cropped fields of the nation's farms.

A report by the Soil Conservation Service claims that four out of every five acres in farms and ranches in Oklahoma, or 80 percent of the farm land of the state, is being damaged by soil erosion, or has lost some topsoil.[2] Soil Conservation Service surveys show that erosion has removed more than three-fourths of the topsoil from 8,543,000 acres of land in farms and ranches.[3] Thirteen million, four hundred sixty thousand acres have lost between one-fourth and three-fourths of its topsoil.[4] On land in farms and ranches erosion is said to be damaging 76 percent of the cropland, 92 percent of the grazing land, 85 percent of the woodland, and 95 percent of the idle land.[5]

---

[1] Ibid.

[2] State Soil Conservation Committee, "Oklahoma Soil Conservation Service," Biennial Report, (December, 1943-1944), p. 5.

[3] Ibid.

[4] Ibid.

[5] Ibid.

Of the state's 44,314,120 acres, 34,803,317 acres are in farms and ranches and less than 5,000,000 of these acres have suffered no erosion.[1]

It has been estimated that every year erosion removes 126 billion pounds of plant-food material from fields and pastures. This amount is more than twenty-one times as much as is extracted by crops, and the process entails an annual loss to farmers of at least $400,000,000.[2]

From the study of the extent of soil erosion, it may appear that much damage has been done to our soil as a result of soil erosion; that many tons of fund resources are being taken away from farms annually by water and wind; that many pounds of plant nutrients are being washed into streams and rivers and such removals result in many dollars lost to farmers annually. While there are heavy losses of plant food materials resulting from soil erosion, the question remains as to its economic significance. If America has been losing twenty-one times the annual use, the inquiry could well be made as to its need relative to other goods and services. If Americans saved the plant food materials, sacrifices would be necessitated in other areas of the economy. These other areas are regarded dearly by virtue of choices, as evidenced by preferences in the form of economic demand. These aspects

---

[1] Ibid.

[2] Maxwell S. Stewart, "Saving Our Soil," Public Affairs Pamphlet No. 14 (1937), p. 2.

apparently are not considered in the valuation assessed on the plant food lost. In expressing an economic loss resulting from plant food material removal by erosion, it appears that an accounting of the cost to prevent the removal of plant nutrients should be taken under consideration. For example, if the cost of preventing plant-food material removal is $600,000,000 annually and the value of the plant-food material is $400,000,000 annually, then the farmers would not suffer a loss.

One may well feel like asking the question, what should be the desired maximum or minimum goal in preventing soil and plant food material removals resulting from soil erosion? It sometimes appears to be the aim of some people to forestall geological erosion. This type of erosion would occur regardless of man's activities. If citizens treat all geological erosion as undesirable they may even prevent soil formation. Do citizens want to restrict exploitation or disinvestment as a maximum goal? Do they want to maintain soil fertility? Both these goals may restrict the rights of individuals to transfer capital.

In the opinion of the writer, it seems to be characteristic of human nature to attempt, by some self-limiting ordinance, to avoid thinking outside one's own specialty. The soil conservationist should be ready to venture into economics, psychology or history as occasion may demand, in order to state truths more nearly completely. There appears to be a great need for the United States Soil Conservation Service to bring into its department trained economists and to undertake cooperative studies with soil conservationists and economists in order that an unbiased presentation of information on the "costs" of soil erosion can be made.

Economic appraisals of "costs" can only be properly made under the assumptions prescribed by economic principles. Unfortunately, "pseudo-economic" appraisals are sometimes made without recognition of fundamental economic principles. It appears to the writer that such efforts are more harmful than helpful to the cause of preventing soil erosion, because they do not get at the critical aspect of conservation, namely: relative costs of erosion.

CHAPTER IV

YIELD LOSSES RESULTING FROM SOIL EROSION

A survey of many writings suggests that the potential increase in agricultural output resulting from the vast improvements made in the science of crop production in past years has been offset in large measure by the damage to the soil resulting from the action of wind and water in the erosion process.

Since the previous chapter examines the extent of soil erosion, it is the purpose of this chapter to show the actual yield losses resulting from soil erosion.

According to Bennett's opinion, there are still a few who question the fact that crop yields are lowered by erosion.[1] He states that farmers all over the country recognize that crop yields have been reduced because of the loss of topsoil, and in spite of the success achieved in breeding better varieties of crops and the increased employment of improved farm machinery designed for more efficient tillage, and regardless of the more general use of improved crop rotations, lime, and various soil fertilizers, and with all the

---

[1]Bennett, op. cit., p. 213.

the education provided in the schools of every state and in books, bulletins, the press, garden clubs, agricultural colleges, experiment stations, and farmers' meetings, the nationwide average yield of crops has not increased to an important degree in the United States.[1]

George H. Walter of the Bureau of Agricultural Economics points out that experiments in the northern states, for example, show that on the average the loss of an inch of topsoil from an acre of cropland reduces annual corn yields by 2 to 6 bushels; oat yields by 1.5 to 5.5 bushels; wheat yields by 0.7 to 3 bushels; potatoes by 5 to 10 bushels and hay by 200 to 400 pounds per acre.[2] Walter states, however, that more studies of these crops are needed before definite relationships between yield and topsoil depth can be accurately determined.[3]

Walter further brought out that field experiments indicate that the loss of an inch of topsoil has less effect on crop yields where the topsoil is deep than where it is shallow.[4] Yields of corn on land on which the topsoil was 11 inches deep was about 3 bushels per acre less than on land

---

[1] Ibid.

[2] George H. Walter, "One Inch Topsoil = ? Bushels," The Agricultural Situation, (February 1950), p. 10.

[3] Ibid.

[4] Ibid.

on which the topsoil was 12 inches deep. On land with 3 inches of topsoil, however, corn yields averaged 5 to 6 bushels less than on land with 4 inches of topsoil.[1]

Bennett, in his book on Soil Conservation, states that information pertaining to the effect of soil erosion on yield has been acquired at various soil and water experiment stations.[2] He states that in the experiments the same crop was grown on adjacent areas, one with its topsoil, or a considerable part of it remaining, the other stripped of topsoil down to clay subsoil (the B horizon). The same variety of crop was grown on each set of contrasting plots, with the same number of plants in each and with identical cultural methods applied at the same time.[3]

Since the slope was identical, and rainfall the same on both areas, it appears reasonable to conclude that for the periods involved, the results probably are as accurate as scientific technique could make them. It was pointed out by Bennett that the measurements were considered significant, particularly for humid and sub-humid conditions because they were made for the most part on widely separated types of land carefully selected for their representativeness with respect

---

[1] Ibid.

[2] Bennett, op. cit., p. 215.

[3] Ibid.

to the erosion hazard within problem areas comprising some 200 million acres of land, much of it cropland.[1]

The results of these determinations are presented in Table 1, where the soil has been stripped down to the subsoil level, as erosion has removed it from more than 100 million acres, or 9.73 percent of the total cropland in the United States, of what formerly was fair to good cropland. The average production for the ten types investigated was 77 percent below that of the corresponding areas still retaining a good cover of topsoil. With respect to individual types, the maximum decline of productivity, as between soil and subsoil, was from 35.3 to 1.1 bushels of corn per acre (97 percent reduction), in the instance of muskingum silt loam. The minimum decline has been from 495 to 313 pounds of seed cotton an acre (37 percent reduction) on Vernon fine sandy loam.

A study was conducted with corn in Iowa in 1936 and with corn and oats in 1937 to determine the relationship of soil type and soil depth to corn and oat yield.[2] As a result it was found that yields vary not only with soil types, but also, and more importantly, with depth of soil on the same soil

---

[1] Ibid.

[2] William G. Murray, A. J. Englehorn and R. A. Griffin, "Yield Test and Land Valuation," Iowa Agricultural Experiment Station Research Bulletin No. 252 (March, 1939), pp. 55-76.

TABLE 1

AVERAGE ACRE YIELDS FROM TOPSOIL AND CORRESPONDING SUBSOIL OF TEN REPRESENTATIVE TYPES OF FARM LAND UNDER COMPARABLE CONDITIONS OF SLOPE, RAINFALL, AND CULTURAL TREATMENT[1]

Type of land	Soil Amendment	Rainfall inches	Period inclusive	Crop	Average yield Topsoil	Average yield Subsoil	Yield decline percent
Houston black clay. 4% slope Texas	 None	26.56 38.95 32.76	1931,1934 1932,1935 1933,1936	Corn Oats Cotton[2]	26.8 bu. 60.6 bu. 288 lb.	2.9 bu. 22.5 bu. 102 lb.	89 63 64
Marshall silt loam, 9% slope Iowa	None	27.3	1932-1935	Corn	30.7 bu.	6.5 bu.	79
Clinton silt loam, 16% slope Wisconsin	None	32.6	1933-1934	Corn	49.3 bu.	21.2 bu.	57
Muskingum silt loam, 12% slope Ohio	None	39.5	1936	Stover	4,258lb.	510 lb.	88
Palouse silt loam, 30% slope Wash.	None	21.7	1932-1935	Winter Wheat	23.9 bu.	7.2 bu.	70
Colby silty clay loam, 5% slope, Kan.	None	19.9	1931-1935	Winter Wheat	12.5 bu.	5.3 bu.	58

See footnotes on next page.

TABLE 1--Continued

Type of land	Soil Amendment	Rainfall inches	Period inclusive	Crop	Average yield Topsoil	Average yield Subsoil	Yield decline percent
Kirvin fine sandy loam 8.75% slope Tex.	None			Cotton	365 lb.	50 lb.	86
	400lb.4-8-4 fertilizer	40.6	1931-1934	Cotton	580 lb.	206 lb.	65
	None		1931-1934	Cotton	308 lb.	131 lb.	96
Nacogdoches fine sand loam 10% slope Texas	400 lb. 4-8-4 fertilizer & green manure	34.4	1936	Cotton	450 lb.	130 lb.	71
Cecil sandy clay loam, 10% slope N.C.	None	46.1	1932-1934	Cotton	950 lb.	290 lb.	69
Vernon fine sandy loam, 7.7 % slope, Okla.	None	30.9	1929-1936	Cotton	159 lb.	96 lb.	39
	Virgin soil	33.1	1930-1935	Cotton	495 lb.	313 lb.	37

[1]Measurements at soil and water conservation experiment stations, Soil Conservation Service.

[2]Lint cotton; other cotton yields relate to the unginned product ("seed cotton").

Source: As compiled by H. H. Bennett, Soil Conservation, (New York, 1939), p. 216.

type. Corn yields decreased from 53 to 31 bushels per acre on Tama Silt loam in 1936 with a decrease in depth of surface soil from 12 to 0 inches.[1]

In 1937, both with corn and oats, experiments reveal that corn yield in 1937 decreased from 88 bushels to 47 bushels per acre as the depth of topsoil decreased from 12 to 2-0 inches. The average acre-yield of corn on Tama silt loam, as related to depth of topsoil during the two year period, 1936-37, and oats in 1937, are shown in Table 2. These data indicate that the depth of topsoil, particularly from 7 inches downward, has a pronounced effect on corn yields on Tama silt loam.[2] The results with corn grown on this soil were substantiated by data obtained on Clarion loam and Clarion fine sandy loam during 1937.[3] Clarion loam which, after erosion, had less than 7 inches of topsoil remaining, produced 51 bushels of corn per acre, whereas the same type of soil with over 7 inches of topsoil produced 67 bushels. Corresponding yields for Clarion fine sandy loam were 39 bushels per acre with less than 7 inches of topsoil and 54 bushels with more than 7 inches of topsoil remaining.[4]

---

[1] Ibid., p. 66.

[2] Ibid.

[3] Ibid., pp. 70-73.

[4] Ibid., p. 73.

TABLE 2

EFFECT OF DEPTH OF TOPSOIL ON YIELD OF
CORN AND OATS ON TAMA SILT LOAM

Depth of surface soil, in inches	Corn				Oats	
	1936		1937		1937	
	No. of samples	Average yield	No. of samples	Average yield	No. of samples	Average yield
		Bu. per acre		Bu. per acre		Bu. per acre
0-2	4	31	7	47	0	--
3-4	8	28	10	69	2	52
5-6	30	39	19	77	7	61
7-8	39	~~49~~ 45	33	82	11	70
9-10	23	50	19	88	4	72
11-12	12	50	25	82	4	70
13+	11	53	19	88	2	64

Source: Compiled from average yields, according to Soil Type and Depth 1936-1937. Yield Tests and Land Valuation, Iowa Agri. Exp. Sta. Res. Bul. 252, (March, 193~~6~~9), p. 66.

For the year 1936 there is a decrease in the yield of corn per acre from 31 bushels on soil 0-2 inches in depth to 28 bushels per acre on topsoil 3-4 inches in depth (Figure 1). The graph also indicates that a reverse condition resulted in 1937 when the yield of corn per acre increased from 47 bushels on topsoil 0-2 inches in depth to 69 bushels per acre on soil 3-4 inches in depth. The graph shows that there is a continuous increase in the yield of oats per acre in 1937 on soil from 0-2 inches in depth up to 9-10 inches. The yield of oats per acre decreased on topsoil over 10 inches in depth.

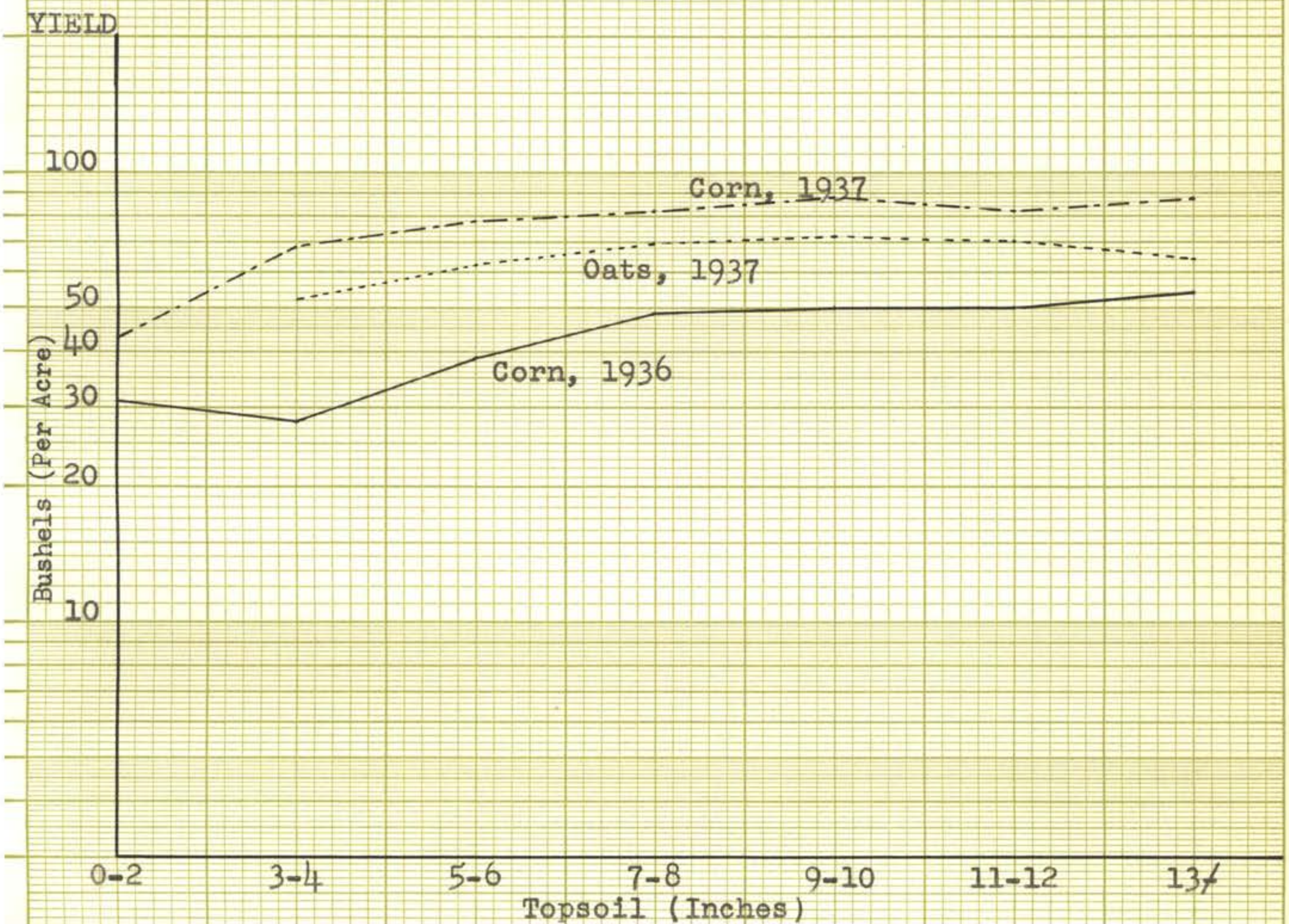

FIGURE 1. EFFECT OF DEPTH OF TOPSOIL ON YIELD OF CORN (1936 AND 1937) AND OATS (1937) ON TAMA SILT LOAM IN IOWA

SOURCE: Table 2.

Studies were conducted on three watersheds at Coshocton, Ohio, in 1941 to determine the relation of the depth of topsoil to corn yields. The experiments were made under similar conditions of soil type, rainfall, varieties, and cultural practices.[1]

Yield measurements made on 4, 5, 6, 7, 8, and 9 inches in depths of topsoil on each watershed expressed in bushels per acre were 33.7, 41.2, 46.4, 50.9, 51.1 and 59.5 respectively, (Figure 2). The yield where 9 inches of topsoil remained was 59.5 bushels per acre as compared with 33.7 bushels where 4 inches of topsoil remained. This represents an actual reduction of 5.2 bushels per acre for each inch of soil below 9 inches. The yields for the depths between were 41.2 bushels for 5 inches, 46.4 bushels for 6 inches, 50.9 bushels for 7 inches and 51.1 bushels for 8 inches. There is but 2.1 percent of the area of the watershed that has soil as deep as 9 inches; 50 percent of the total area had 6 inches or less of topsoil.[2]

Studies conducted on corn yield and depth of soil were made on ten fields of Marshall silt loam at Shenandoah, Iowa,

---

[1]R. E. Uhland, Crop Yields Lowered by Erosion, United States Department of Agriculture, Soil Conservation Service. In Cooperation with Agricultural Experiment Stations of Indiana, Ohio, Iowa and Missouri (February, 1949).

[2]*Ibid.*, p. 16.

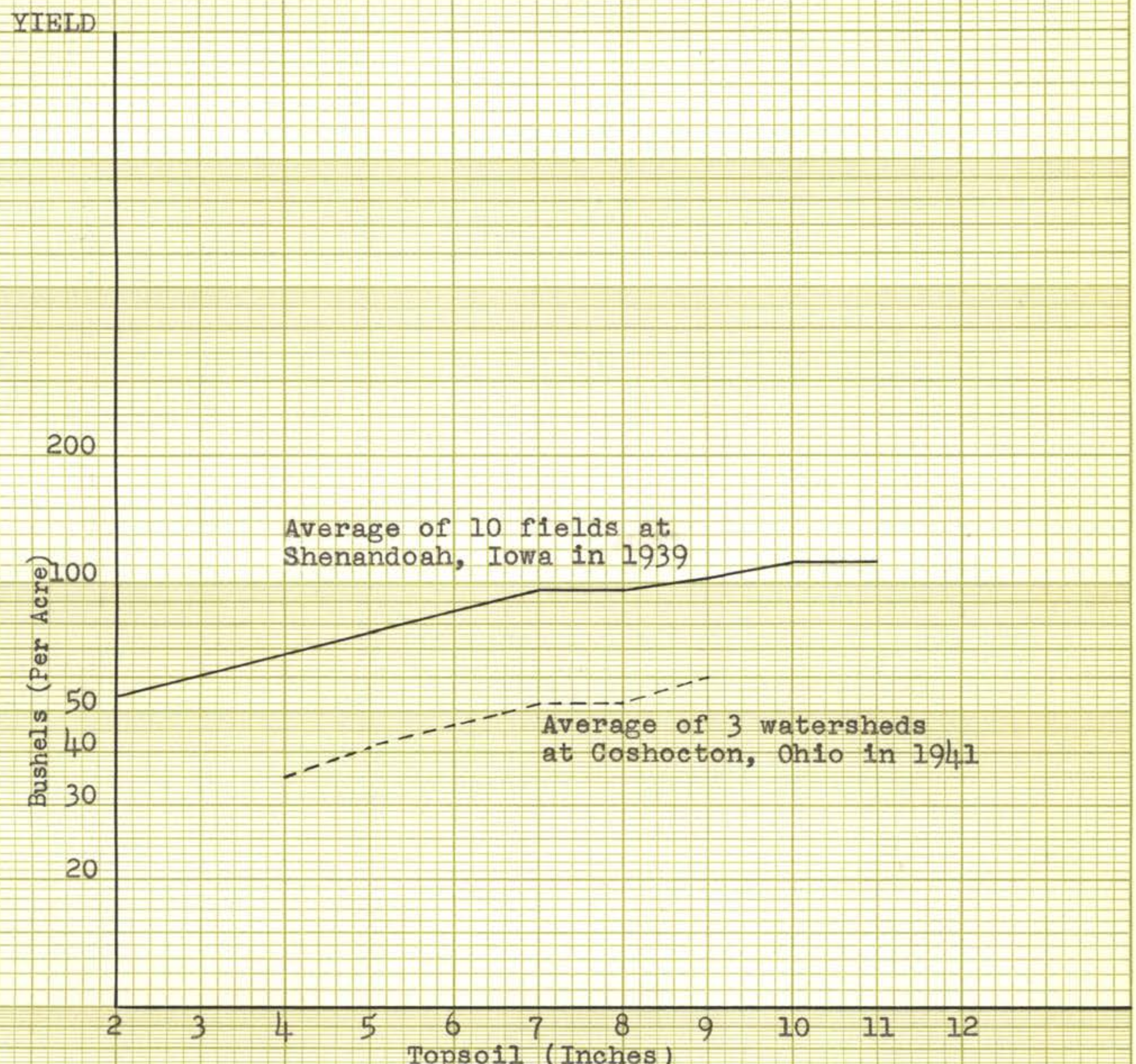

FIGURE 2. CORN YIELDS EXPRESSED IN BUSHELS PER ACRE FOR DIFFERENT DEPTHS OF TOPSOIL IN IOWA AND OHIO

SOURCE: J. H. Stallings, Erosion of Topsoil Reduces Productivity, United States Department of Agriculture SCS-TP-98 (August 1950), p. 16.

in 1939.[1] These studies were made under the same climatic conditions, varieties of seed, and cultural practices, but on different depths of soil.[2] The yields ranged from 119.9 bushels per acre where the depth was approximately 1 foot, to 52.3 bushels where but 1 to 2 inches of the topsoil remained, a difference of 67.6 bushels of corn. This represents an actual reduction of 6.2 bushels per acre for each inch of soil below 12 inches.

The yields for the depths between were 61.5 bushels per acre for 3 inches of topsoil; 68 bushels per acre for 4 inches of topsoil; 76.2 bushels per acre for 5 inches of topsoil; 83.5 bushels per acre for 6 inches of topsoil; 88.5 bushels per acre for 7 inches, 96.8 bushels per acre for soil 8 inches deep; 104 bushels per acre for soil 9 inches deep; 115.5 bushels per acre for 10 inches of topsoil and 114.6 bushels per acre yield for 11 inches of topsoil.[3] Investigations of the yield of corn made on ten fields of marshall silt loam at Shenandoah, Iowa, in 1938 indicates that the total yield per acre of corn made a continuous increase from 52.3 bushels per acre on soil 2 inches in depth to 115.5 bushels per acre on soil 11 inches in depth (Figure 3).

---

[1]J. H. Stallings, Erosion of Topsoil Reduces Productivity, United States Department of Agriculture, Soil Conservation Service. SCS-TP-98 (August, 1950), pp. 15-17.

[2]Ibid., p. 16.

[3]Ibid.

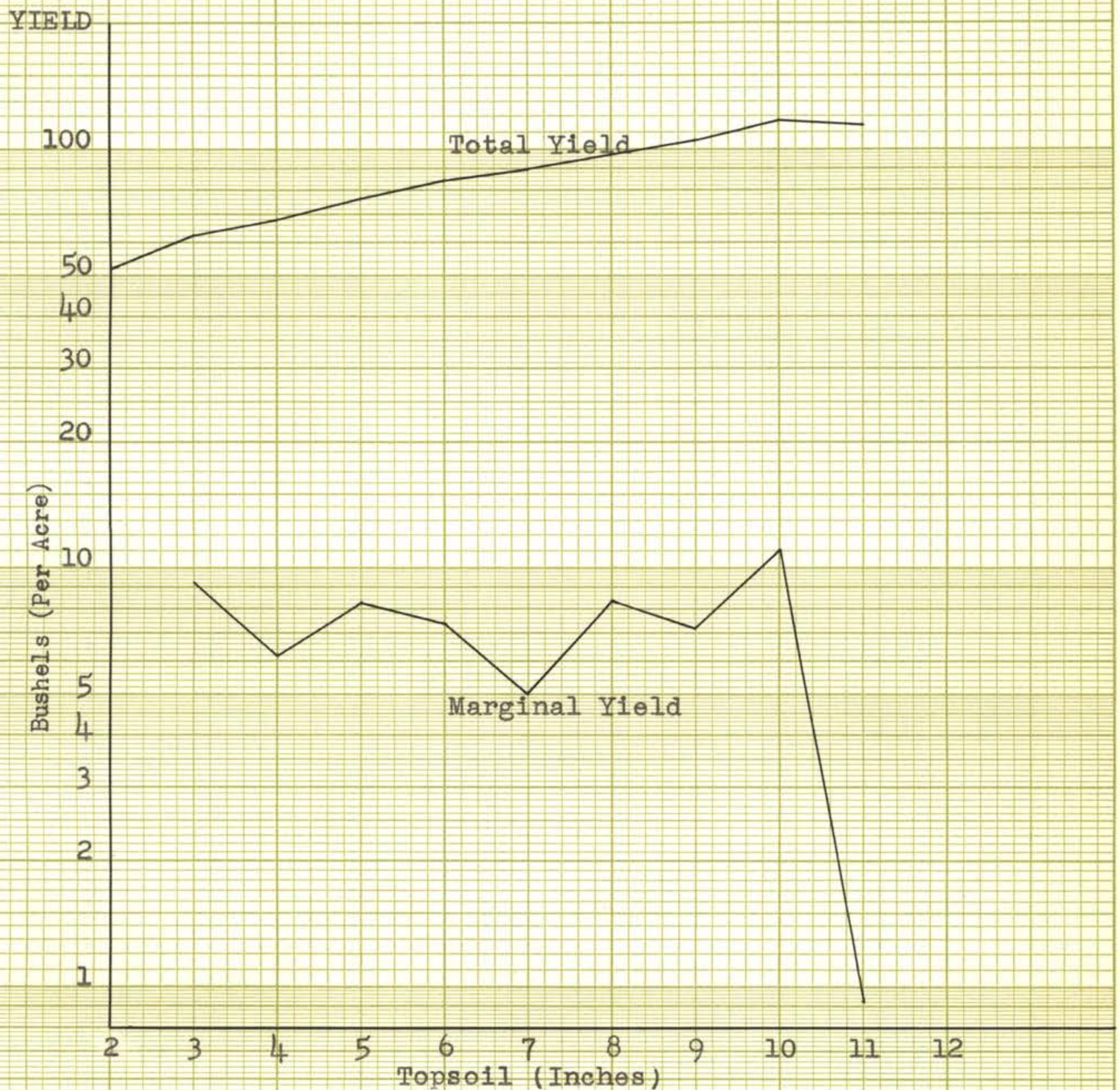

FIGURE 3. TOTAL YIELD AND MARGINAL YIELD EXPRESSED IN BUSHELS PER ACRE FOR DIFFERENT DEPTHS OF TOPSOIL

SOURCE: Table 3.

It will also be noted on the graph that the marginal yield per acre did not increase continuously as the depth of the topsoil increased. This seems to indicate that soil erosion affects the yield on shallow soil in the same degree that it affects the yield per acre on deeper soil.

In New Jersey yields of nine crops were measured over varying periods of time on areas with less than 6 inches of topsoil and on other areas with more than 6 inches to determine the relationship between yields and depth of topsoil.[1] These experiments were made under similar climatic conditions, soil type, varieties of seed, and cultural practices. There was a significant difference in yields in every case in favor of the greater depth of topsoil[2] (Table 3).

The yield of potatoes per acre for soil depth of 0 to 6 inches was 233 bushels and for potatoes grown on soil 6 inches or more in depth 298 bushels per acre, or a difference of 65 bushels or an increase of 27.8 percent. Corn yield was 40 bushels per acre for soil less than 6 inches deep and 64 bushels per acre for soil more than 6 inches deep, a difference of 24 bushels, or 37.5 percent, increase in yield. Wheat production was increased from 17 bushels per acre on soil 6

[1]Soil Conservation Service, New Jersey Agricultural Experiment Station and State Soil Conservation Committee, Soil Conservation Research in New Jersey, United States Department of Agricultural Soil Conservation Service and New Jersey State Soil Conservation Committee, (1948), pp. 1-21.

[2]*Ibid.*, p. 3.

TABLE 3

CROP YIELDS PER ACRE FOR VARIOUS DEPTHS OF TOPSOIL, NEW JERSEY

	Depth of topsoil		Difference in Yield	Percent Increase in Yield
	0 to 6 inches	6 inches or more		
	Bushels	Bushels	Bushels	Percent
Potatoes	233	298	65	27.8
Corn	40	64	24	37.5
Wheat	17	34	17	100.0
Oats	21	32	11	52.4
Soybeans	4	18	14	350.0
Barley	26	55	29	111.5
Rye	11	37	16	145.0
Alfalfa	2*	3.3*	1.2*	60.0
Asparagus	232**	728**	496**	213.0

Source: Soil Conservation Service, New Jersey Agricultural Experiment Station, and Soil Conservation Committee. Soil Conservation Research in New Jersey. U. S. Dept. Agr. Soil Conserv. Serv., N. J. Agr. Expt. Sta., and N. J. St. Soil Conserv. Com. 21 pp., Illus. 1948 (Mimeographed).

*Tons

**Pounds

inches and less to 34 bushels per acre on soils more than 6 inches, or an increase of 100 percent.

The yield of oats on soil less than 6 inches deep is 21 bushels per acre and on soil more than 6 inches 34 bushels per acre; oat yields show an increase of 11 bushels, or 52.4 percent per acre. Soybean yield was 4 bushels per acre on soil more than 6 inches, a difference of 14 bushels per acre, or a 350 percent increase. Barley yield was 26 bushels per acre on soil less than 6 inches and 55 bushels on soil with a depth of more than 6 inches. There was a difference of 29 bushels, or an increase of 145 percent in yield on the soil more than 6 inches in depth.

Rye shows an increase in yield from 11 bushels per acre on soil less than 6 inches to 37 bushels per acre on soil more than 6 inches, a difference of 16 bushels, or 145 percent increase.

Alfalfa production was increased from 2 tons per acre on soil less than 6 inches to 3.3 tons per acre on soil with more than 6 inches of depth, a difference of 1.2 tons,or an increase in yield of 60 percent.

Asparagus yield was 232 pounds per acre on soil less than 6 inches and 728 pounds per acre on soil more than 6 inches in depth, a difference of 496 pounds per acre or a yield increase of 213 percent.

A study of corn yield in relation to depth of topsoil for each of 16 fields in the Fowler, Indiana, area was made in 1939.[1] The depth of topsoil ranged from 1 to 13 inches for the 16 fields. The average yield for the 16 fields ranged from 44.1 bushels per acre where all the topsoil had been removed by erosion to 89.9 bushels for the 13+ inches of topsoil that still remained (Table 4).

The 1 to 2 inch depth of topsoil produced only 52.6 percent as much corn as did the soil that was 13 inches or more in depth. The range in corn yield was from 31.3 bushels per acre for 0 to 2 inches of topsoil remaining to 119.7 bushels per acre for soil 13+ inches deep, or a difference of 88.4 bushels of corn per acre.

There was a difference of 45.8 bushels in the average yield from soil having 13 or more inches as compared with those having depths of 1 to 2 inches. This is a reduction of 47.3 percent in yield for the corn grown on the 1 to 2 inch depth of topsoil. In other words, the deepest soil yielded 1.89 times as much as the shallowest soil. For each inch of soil loss there was an average reduction in yield of 4.1 bushels of corn per acre.

The average depth of topsoil for each of the 16 fields studied ranged from 6.7 inches to 11.7 inches. The average yield per acre for each of the 16 fields ranged from 55.8 bushels to 108.8 bushels.[2]

---

[1] R. E. Uhland, Crop Yields Lowered By Erosion, United States Department of Agriculture, Soil Conservation Service. SCS-TP-75 (February, 1949), pp. 8-12.

[2] Ibid., p. 9.

TABLE 4

AVERAGE YIELD OF CORN FROM DIFFERENT SOIL DEPTHS
ON 16 FIELDS AT FOWLER, INDIANA, 1939

Field Number	Depth of topsoil and bushels per acre 13"+	11 to 12"	9 to 10"	7 to 8"	5 to 6"	3 to 4"	0 to 2"	Average depth Inches	Average yield, Bu. Per acre
1	66.6	72.2	68.0	58.7	59.8	54.4	31.3	8.6	61.2
2	113.3	89.8	81.6	76.8	70.7	59.8	35.4	11.7	84.3
3	87.1	88.4	74.8	78.9	80.2	71.7	51.7	8.4	77.5
4[1]	119.7	115.6	115.6	107.4	104.7	89.8	62.6	9.2	108.8
5[1]	114.2	106.1	109.8	102.0	90.2	70.7	51.7	8.0	95.2
6	112.2	104.9	97.1	98.6	95.2	87.7	62.1	7.9	96.6
7	78.9	85.7	85.7	68.0	66.6	61.2	51.7	8.0	72.1
8	95.2	92.5	89.8	83.1	81.6	72.2	54.0	6.7	77.0
9	74.8	68.8	66.1	53.9	49.4	47.6	38.0	8.1	57.1
10	80.0	71.4	61.5	57.5	53.5	53.2	34.0	8.3	58.5
11	77.5	78.9	77.5	73.9	62.3	44.9	35.4	8.1	69.9
12	84.9	80.0	62.7	56.6	52.6	44.9	32.0	7.2	55.8
13	90.4	82.3	62.0	51.7	45.8	39.4	34.0	8.1	55.8
14	60.3	85.4	87.6	74.8	68.0	52.1	43.0	8.8	76.2
15	89.6	83.0	72.8	70.3	59.2	53.0	40.0	8.0	68.0
16	94.1	83.5	84.3	68.8	53.7	51.0	48.9	9.5	76.2
Average yield	89.9	86.8	81.1	73.8	68.3	59.6	44.1	8.4	74.4

[1]Fields 4 and 5 were in bluegrass pasture for 20 years prior to 1938, but prior to 1918 had been cropped frequently to corn 4 or 5 years in succession. Management differences account for marked variations in yields for same depth class or for different fields.

Source: The Survey and yield data on the Fowler Project were secured by the cooperation efforts of the regional, area, and personnel of the Soil Conservation Service as compiled by R. E. Uhland, "Crop Yields Lowered by Erosion," U. S. Dept. of Agr. SCS-TP-75 (February, 1949), p. 12.

Finnell, in a study of the decline of productivity of High Plains Wheatlands due to crop removals and erosion, points out that erosion has been robbing the wheat farmers' land of part of its possible yield.[1]

He points out in his study that soil erosion does not account for all of the declines of productivity. Part of the loss of yield must be charged to depletion of fertility due to removal of nutrients in the crops harvested.[2]

In his study he used both the losses of productivity due to cropping and to soil erosion. The losses of productivity due to cropping and to soil erosion are shown separately (Table 5). This separation was made by noting the average degree of erosion in the different age classes of cultivated land, and then subtracting the decline of wheat yield due to erosion alone from that caused by length of cultivation and erosion combined. This provided a basis for calculating the rate of soil depletion due to unreplaced removals of nutrients of crops.[3]

There is a gradual decline of 2.8 bushels per acre in yielding power due to cropping over a period of 27 years, and a 4.2 bushels per acre in yielding power due to erosion over

---

[1] H. H. Finnell, Depletion of High Plains Wheatlands, United States Department of Agriculture, Circular No. 871 (June, 1951), pp. 1-18.

[2] Ibid., p. 9.

[3] Ibid., pp. 6-7.

TABLE 5

AVERAGE PER-ACRE DECLINE OF PRODUCTIVITY OF HIGH PLAINS WHEATLANDS DUE TO CROP REMOVALS AND EROSION

Kind of Land	5-year Average Yield of Wheat	Loss of productivity due to removals		
		Crops	By Erosion	Total
	Bushels	Bushels	Bushels	Bushels
New land[1]	26.1	0.0	0.0	0.0
6-year-old land	23.3	.5	2.3	2.8
27-year-old land	19.1	2.8	4.2	7.0

[1]Average length of time in cultivation, 2 years.

Source: Depletion of High Plains Wheatlands, Circular 871, United States Department of Agriculture, (June, 1951), p. 9.

the same period. There is a decline of only .5 of a bushel per acre in yielding power due to cropping over a period of 6 years compared to 2.3 bushels per acre in yielding power due to erosion for the same period of years.

Finnell points out that where soil depletion is allowed to run wild, and soil nutrients are removed by both crops and erosion, the accumulation loss in the first ten years due to erosion would be four and one-half times as much as that due to crop removals. At the end of 30 years it would still be one and one-half times as great. It is the early damage of soil erosion that proves most expensive in the end.[1]

[1]Ibid., p. 10.

Studies made by O. E. Hays and C. O. Rost indicate that the yield of oats obtained on five widely scattered farms in southeastern Minnesota from areas that were as nearly uniform as possible with the exception of depth of topsoil show some correlation. Plots were selected on slightly or uneroded, moderately eroded and severely eroded fields. The yield of oats on uneroded soil with 10 or more inches of surface soil is 36.1 bushels per acre. The yield on moderately eroded soils, with 5 to 10 inches of surface soil remaining, is 30.0 bushels; and the yield on severely eroded soil, with 5 or less inches of surface soil remaining is 22.7 bushels per acre.[1] In other words, the uneroded soil, or the soil 10 or more inches in depth, produced 6.1 bushels more oats per acre than the moderately eroded soil, 5 to 10 inches in depth. The moderately eroded soil produced 7.3 bushels more per acre than the severely eroded soil.

According to Uhland's opinion, erosion has lowered crop yields throughout the country generally, and has resulted in abandonment of both large and small areas.[2] Some of the

---

[1]O. E. Hays, and C. O. Rost, The Effect of Depth of Surface Soil and Conturing on Crop Yields, Soil Conservation Service and Minnesota Agricultural Experiment Station, Mimeo., 1944.

[2]R. E. Uhland, "Field Methods of Evaluating Effects of Physical Factors and Farm Management Practices on Soil Erosion and Crop Yields," Soil Sci., Soc. Amer. Proc., 5:373-376,1940.

abandoned land may have been too shallow for cultivation at the time it was broken out, but much of it was reduced in depth by soil erosion to the point where it became too shallow for cultivation. Once reduced to a depth insufficient for adequate water storage for crop growth, such lands are virtually lost to the growing of cultivated crops except under irrigation, regardless of the inherent productivity of the soil material.[1] Walter suggests that once the topsoil is gone there is no way of regaining the productive capacity that vanishes with the topsoil.[2] He points out that crop yield studies all over the country indicate that the original material out of which a soil is formed determines inherent productive capacity of that soil. Each inch of topsoil with its accumulation of humus and plant nutrients adds to the expected yield.[3]

He further states that total yields of a soil are affected by cultural practices and physical conditions, such as rainfall and temperature, but these factors have little or no effect on differences in yields resulting from variations in topsoil thickness.[4]

---

[1] Ibid.

[2] Walter, op. cit., p. 11.

[3] Ibid.

[4] Ibid.

A review of data on yield losses associated with soil erosion reveals that many of the experiments were conducted so that factors such as cultural practice, climatic conditions, and soil type were similar. For example, the experiment determining the acre yield from topsoil and corresponding subsoil of ten representative types of farm land under comparable conditions of slope, rainfall and cultural treatment reveal that the topsoil and subsoil were of colby and silty clay loam, both topsoil and subsoil had a 5 percent slope and received 19.9 inches of rainfall for the growing season. The yield of wheat per acre was 12.5 bushels on the topsoil and 5.3 bushels per acre on the subsoil, or a decline in yield of 58 percent for the yield of wheat on the subsoil. (Table 1).

An analysis of data of the studies conducted in Iowa in 1936 and 1937 reveals no information as to the conditions under which the experiments were made. An analysis of data of a study of the relationship of soil type and soil depth to corn and oat yield conducted in Iowa reveals no information as to similarity of cultural practice, climatic conditions and variety of seed used on different soil depths. If, under these conditions, the experiment was conducted, it might well be concluded that the difference in yield from varying depths of topsoil could have been attributed to any one factor affecting yield.

Most of the data show a decrease in yield to be associated with a decrease in the depth of topsoil; however, some data reveal an increase in yield as the depth of the topsoil decreases, and some reveal no change in yield as an increase in topsoil depth. In pointing out the fact that yield may increase as the depth of topsoil decreases, it may, therefore, be well to give particular attention to those data which show relationships which are inconsistent with the general tendency for soil erosion to be associated with decreased yields. This is shown in an analysis of data of an experiment in Iowa during 1936-1937 which reveals that the yield of corn on topsoil 2 inches in depth is 31 bushels per acre and the yield from topsoil 4 inches in depth is 28 bushels per acre or 3 bushels less in yield on the deeper soil. The analysis further reveals that topsoil 10 inches in depth yields 50 bushels of corn per acre as compared to the same yield on topsoil 12 inches in depth.

Unquestionably the data on yield losses associated with erosion damage are very useful. It is the opinion of the writer that more complete studies which show the relationship between yield loss and soil erosion should be made. Many of the data appear to be based on empirical studies which provided inadequate measurement of the yield loss which could be attributed strictly to soil erosion.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study presents information on three separate but related questions on soil conservation. First, consideration is given to the applicability of current analytical definitions of soil conservation. The second and third inquiries deal with the extent of soil erosion and the yield losses resulting from soil erosion.

The introductory chapter lists the purpose of the study and describes the procedure used to get information on the questions discussed. As a preliminary procedural preparation for gathering information an investigating "key" was formulated, designating the subject topics to be investigated in the review of literature. After a preliminary effort the "key" was modified slightly and as used includes the following subjects: agriculture, conservation,economics, erosion, land, production, soil conservation, soil erosion and yield. Besides the review of literature an extensive number of personal interviews and letters of inquiry were undertaken to gather information.

The objective of Chapter II is one, to give a brief summary of definitions of conservation, soil conservation, and soil; and two, to discuss the applicability of two current definitions of soil conservation--that of Arthur C. Bunce, and the joint contribution of Earl O. Heady and O. J. Scoville.

From a study of definitions of "conservation" it appears that it has different meanings for different people and for different times. Broadly interpreted, it may be concluded that conservation includes a set of principles that deal with every activity and resource use that affect public and private welfare. Thus in using the term conservation, it is essential that its scope be defined and the particular resources to which it applies be designated; otherwise, its meaning is so broad that it has little significance.

Soil designates the sur-ficial portion of the earth, the layer extending from the surface down to some decided change in the texture, color, or structure of the material, a composite resource containing fund resources (soil body), flow resources (soil fertility) and biological resources (part fund and part flow resources), it may be only a few inches deep or it may be a foot or more. This portion is frequently referred to as surface soil.

Bunce emphasizes that soil conservation is the maintenance of the fund resources and the present level of productivity of the soil, assuming a given state of the arts. To maintain the fund resource would necessitate that the inanimate soil body be kept in its present state permanently, undiminished and unimpaired. If conservation were understood in this sense, it appears that soil formation and soil deterioration would have to remain zero.

Bunce's definition requires that the physical factors of the soil must remain constant. There appears to be inadequate distinction made in the difference between the "maintenance" of the fund resource (which can be considered as being fixed) and the flow resource (which can be considered as being a variable resource). The fact that a given yardstick is applied to such a heterogeneous composite (soil) poses, it seems, serious difficulties of measurements. As a result "conservation" is difficult to designate.

Heady's and Scoville's definition stresses the prevention of diminution in 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). This definition appears to be void of the basic requirement of providing the essence of that which is designated to be defined. For example, the use of the definition for analytical purposes necessitates, also, including with it a secondary definition to provide the basis for measuring the change in the state of the arts. What an inquiry into this definition is likely to find is a change in production due to the variables. It seems that one does not have all the knowledge necessary to make the valuation resulting from each variable.

Because of similarity of data, the writer did not attempt to record all of the available studies on the extent of soil erosion. Chapter III, then, is meant to show a few selected studies which indicate the general pattern of existing studies on the extent of soil erosion, and as a background for clarity of understanding the findings of the extent of soil erosion. A brief review of the definitions of geological erosion and soil erosion is presented. Based on a study of definitions of geological erosion, it appears that "geological erosion" is nature's system of production, distribution, and consumption of soil resources. In deriving an understanding of "soil erosion," it may be concluded that soil erosion represents an accelerated process of denudation and destruction of the fund resource or the inanimate soil body effected by man, beyond that which is caused by natural or geological erosion.

In a study of the extent of soil it is estimated that approximately 1,903,000,000 acres of land area is in the United States, 973,000,000 acres is physically suited for crop production. Of this amount 415 million acres are used for crops. At least 73 million acres are said to be too steep, too severely eroded or otherwise unsuited for cultivation. It is estimated that 80 percent of the cropland has been affected by soil erosion.

Maxwell S. Stewart states--and this is concurred by other writers: H. H. Bennett, former Chief of the United

States Conservation Service, William Clayton Pryor, and the Water Planning Committee of the National Resources Board--that an estimate of 126 billion pounds of plant-food material is removed from fields and pastures yearly.[1] These writers estimate that this amount is more than twenty-one times as much as is extracted by crops, and they indicate further that the process entails an annual loss to farmers of at least $400,000,000. Dr. John Lamb, Superintendent of the United States Conservation Experiment Station, Ithaca, New York, gives similar estimates of annual plant-food material and income loss to farmers.

It may appear that much damage has been done to the soil as a result of soil erosion; that many pounds of plant nutrients are being washed into streams and rivers and such removals result in many dollars lost to farmers annually.

There seems to be over-emphasis on the amount of soil washed and blown away annually. The work should be directed not just at accumulating more data on the extent of soil erosion and what can be done to remedy existing situation, but more toward a sound economic analysis of the practicality of the established control methods. There seems to exist a

---

[1]Maxwell S. Stewart, "Saving Our Soil," Public Affairs Pamphlet No. 14 (1937), p. 2.; H. H. Bennett, Soil Conservation (New York, 1939), p. 11.; H. H. Bennett and W. C. Pryor, This Land we Defend (New York, 1942), p. 35.; and see the Water Planning Committee's report as given by L. E. Fruendenthal, "Flood Control," Science, Vol. 78, p. 446.

strong need for expertly trained economists in the Soil Conservation Service of the United States Department of Agriculture, to work in cooperation with soil conservationists in an effort to present more accurate and valuable information and recommendations. The integrity of the Soil Conservation Service and its employees is not questioned, but rather it is merely suggested that the job is not complete and there is not universal acceptance of either the need or the methods now used. The public confidence may be gained, and consequently, the program can be expanded when the American people can be informed of the many economic aspects involved. With the cooperation of agricultural economists the Soil Conservation Service could make more complete presentations of information on the "cost" of soil erosion. These economic appraisals of "cost" can never be made without the basic assumptions prescribed by economic principles. In the past "pseudo-economic" appraisal, without recognition of basic economic principles, may well have been more harmful than helpful to the cause of preventing soil erosion, simply because they do not get at the critical aspect of conservation, that is, the relative cost of erosion.

Chapter IV presents information concerning yield losses resulting from soil erosion. A survey was made of the writings and experiments on soil erosion and soil conservation of several soil scientists, popular writers, economists and authors, among whom may be mentioned, H. H. Bennett, G. V.

Jacks, R. O. Whyte, Karl B. Mickey, George H. Walter, William G. Murray, R. W. Uhland, J. H. Stallings, O. E. Hays, and C. O. Rost. The writings indicate that the potential increase in agricultural output resulting from the vast improvements made in the science of crop production in modern times has been offset to a great extent by damage to soil resulting from the action of wind and water in the erosion process. For example, George H. Walter of the Bureau of Agricultural Economics points out that experiments in the northern states, show that on the average the loss of an inch of topsoil from an acre of cropland (no data are given on the depth of topsoil) reduces annual corn yields by 2 to 6 bushels. Oat yields are reduced by 1.5 to 5.5 bushels; wheat yields by 0.7 to 3 bushels; potatoes by 5 to 10 bushels and hay by 200 to 400 pounds per acre.

Another test--somewhat more complete--reveals that in 1937 corn experiments showed that the yield decreased from 88 to 47 bushels per acre as the depth of topsoil decreased from 12 to 2-0 inches.

In contrast to this, there may be some question, however, as to the assumption that yields are always lowered by erosion. For example, in one study it was indicated that the yield increased as the depth of the topsoil decreased. This is shown in an experiment in Iowa during 1936-1937 which shows that the yield of corn on topsoil two inches in depth is 31 bushels per acre and the yield from topsoil four inches in depth is 28 bushels per acre or three bushels less in yield on the deeper soil. The study further reveals that topsoil 10 inches in depth yields 50 bushels of corn per acre as compared to the same yield on topsoil 12 inches in depth. Unquestionably the data on yield losses associated with erosion damages are very useful. It is, however, the opinion of the writer that more studies of a greater comprehensive nature should be made to more accurately and completely show the relationships between yield loss and soil erosion.

REFERENCES CITED

Books

Bennett, Hugh Hammond. Elements of Soil Conservation. New York: McGraw-Hill Book Company, 1937.

Bennett, Hugh Hammond. Soil Conservation. New York: McGraw-Hill Book Company, 1939.

Bennett, H. H. and W. C. Pryor. This Land we Defend. New York: Longmans, Green and Co., Inc., 1942.

Blaisdell, Donald C. Government and Agriculture. New York: Farrar and Rinehart, Inc., 1940.

Bunce, Arthur C. Economics of Soil Conservation. Iowa: The Iowa State College Press, 1948.

Burges, Austin Earle. Soil Erosion Control. Atlanta, Georgia: Turner E. Smith and Company, 1936.

Ely, R. T., R. H. Hess, C. K. Leith, and T. N. Carver. The Foundations of National Prosperity. New York: The Macmillan Company, 1917.

Gustafson, A. F. and W. G. Hamilton. Conservation in the United States. Ithaca, New York: Comstock Publishing Company, 1949.

Hilgard, E. W. Soils, their Formation, Properties, Composition and Relation to Climate and Plant Growth. New York: The Macmillan Company, 1921.

Holmes, Arthur. Principles of Physical Geology. New York: The Ronald Press Company, 1945.

Jacks, G. V. and R. O. Whyte. Vanishing Lands. New York: Doubleday, Doran and Company, Inc., 1939.

Jenny, Hans. Factors of Soil Formation. New York: McGraw-Hill Book Company, Inc., 1941.

Lord, Russell. Behold Our Land. Boston, Massachusetts: Houghton Mifflin Company, 1938.

Mickey, Karl B. Man and the Soil. Chicago: R. R. Donnelly and Sons Company, The Lakeside Press, 1945.

Miller, William J. An Introduction to Physical Geology. New York: D. Van Nostrand Company, Inc., 1941.

Rice, C. M. Dictionary of Geological Terms. Ann Arbor, Michigan: Edward Brothers, Inc., 1950.

Sigmond, A. A. J. de. The Principles of Soil Science. London: Thomas Murly and Company, 1938.

Van Hise, C. R. Conservation of Natural Resources in the United States. New York: Macmillan Company, 1910.

Weir, Wilbert Walter. Soil Science. Philadelphia: J. B. Lippincott Company, 1949, revised.

Weitzell, Everett. Economics of Conservation in West Virginia. Wisconsin: University of Wisconsin, 1942.

Worthen, Edmund L. Farm Soils, their Management and Fertilization. New York: John Wiley and Sons, Inc., 1948.

Zimmerman, Erich W. World Resources and Industries. New York: Harper and Brothers, 1951, revised.

Bulletins, Biennial Reports, Articles and Documents

Ciriacy-Wantrup, Siefried V. "Private Enterprise and Conservation," Journal of Farm Economics, XXIV (February, 1942), 75-79.

Collier, George W. "Soil Conservation Service." Journal of Farm Economics, XXIV (1942), pp. 124-125.

Finnell, H. H. Depletion of High Plains Wheatlands. United States Department of Agriculture, Circular No. 871 (June, 1951).

Fruendenthal, L. E. "Flood Control," Science, Vol. 78, p. 446.

Gray, L. C. "Economic Possibilities of Conservation." Quarterly Journal of Economics, XXVII, (1913), 499.

Hammar, Conrad H. "Economic Aspects of Conservation." Journal of Land and Public Utility Economics (1931) p. 282.

Hays, O. E. and C. O. Rost. "The Effect of Depth of Surface Soil and Conturing on Crop Yields." Soil Conservation Service and Minnesota Agricultural Experiment Station, (1944).

Heady, Earl O. and O. J. Scoville, "Principles of Conservation Economics and Policy." Research Bulletin No. 382 Ames, Iowa (July, 1951).

Hockensmith, R. D. "Conservation Farming a Basis for Permanent Agriculture." Classifying Land for Conservation. (Farmer's Bulletin No. 1853, (February, 1943).

Leopold, Aldo. "The Farmer as a Conservationist." American Forest. Washington, D.C. (June, 1939), 1-5.

Murray, William G., A. J. Englehorn and R. A. Griffin. "Yield Test and Land Valuation." Iowa Agricultural Experiment Station Research Bulletin No. 252 (March, 1939).

New Jersey Agricultural Experiment Station. "Soil Conservation Research in New Jersey." Soil Conservation Committee (1948).

Northwest Regional Council. "The Meaning of Soil Conservation." Soil Conservation Outline, (June, 1940), p. 6.

Proceedings of the Conference of Governors. Washington, D.C. United States Government Printing Office, 1909.

Schickele, Rainer. "Economics of Agricultural Land Use Adjustment I. Methodology in Soil Conservation and Agricultural Adjustment Research." Research Bulletin No. 209, Iowa Experiment Station, Iowa State College, (March, 1937), 363.

Shield, Robert H. "Soil Conservation Practice Payments." Report of the Production Marketing Administration. (November, 1948).

Stallings, J. H. Erosion of Topsoil Reduces Productivity. United States Department of Agriculture. Soil Conservation Service. SCS-TP-98, (August, 1950).

State Soil Conservation Committee. "Report on Accomplishment of State Soil Conservation Committee and Soil District Supervisors in Oklahoma." Biennial Report. (1941-1942).

State Soil Conservation Committee. "Report on Accomplishment of Soil Conservation Districts." Biennial Report, (1943-1944).

Steward, Maxwell. "Saving Our Soil." Public Affairs Pamphlet No. 14, (1937).

Uhland, R. E. Crop Yields Lowered by Erosion. United States Department of Agriculture. Soil Conservation Service SCS-TP-75, (February, 1949).

Uhland, R. E. "Field Methods of Evaluating Effects of Physical Factors and Farm Management Practices on Soil Erosion and Crop Yields." Soil Science Soc. Amer. Proc. 5:373-376, (1940).

Underwood, F. L. Flue-cured Tobacco Farm Management. Technical Bulletin No. 64. Virginia Polytechnic Institute Virginia Agricultural Experiment Station, (January, 1939).

United States Department of Agriculture. Soil and Men. Yearbook of Agriculture. Washington, D.C.: United States Government Printing Office, 1938.

United States Department of Agriculture, "No One Can Afford Erosion." Soil Conservation Service. Washington, D.C. United States Government Printing Office, (August, 1947).

United States Department of Agriculture, "Erosion can be Controlled." Soil Conservation Service. Washington, D.C. United States Government Printing Office, (August, 1947).

Walter, George H. "One Inch Topsoil = ? Bushels." The Agricultural Situation. United States Department of Agriculture. Washington, D.C. United States Government Printing Office, (February, 1950).

VITA

Victor Bryant Phillips
Candidate for the degree of
Master of Science

Thesis: THREE SELECTED QUESTIONS ON SOIL CONSERVATION

Major: Agricultural Economics

Biographical and other Items:

Born: January 11, 1920, Dover, Oklahoma.

Undergraduate Study: Langston University, Langston, Oklahoma, 1938-1942.

Graduate Study: Oklahoma A. & M. College, 1952-53.

Experience: Army Air Corps, 1953rd Ordnance Depot and Supply Co., December 1942-1943; in India 1943-1946. Interviewer, Oklahoma Employment Security Commission, 1946; Instructor, Veterans Agricultural Training Program, 1947-1951; Graduate Assistant, Oklahoma A. & M. College, 1952-1953.

Member of Kappa Alpha Psi Social Fraternity and Pi Gamma Mu National Honorary Social Science Fraternity.

Date of Final Examination: April, 1953

THESIS TITLE: THREE SELECTED QUESTIONS ON SOIL CONSERVATION

AUTHOR: VICTOR BRYANT PHILLIPS

THESIS ADVISER: DR. ROBERT L. TONTZ

The content and form have been checked and approved by the author and thesis adviser. The Graduate School Office assume no responsibility for errors either in form or content. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

TYPIST: Elizabeth J. Kerby
KERBY TYPING SERVICE