# One Method for Evaluating Effect of Measures To Prevent Erosion of Topsoil[1]

By George H. Walter

*As an aid to the development of techniques for determining how much farmers can afford to pay for the prevention of soil erosion, the author analyzes available data on the effect of soil erosion on the yield of several crops.*

HOW VALUABLE is topsoil? How much can farmers afford to spend to prevent its erosion? Is complete erosion control practicable? If not, what degree of control should be the farmer's goal? All of these are economic questions that deserve attention and that need answers. But today only a part of the information necessary for the answers is available. And the answer for one type of soil is not always applicable in the case of another soil. But the techniques for obtaining at least part of the answers can be applied wherever the needed research has been completed: it is essential to know how the loss of topsoil affects the yields of crops before these other questions can be answered.

Soil scientists have found that on many soils the expected yields are closely related to the depth or thickness of the topsoil that is present. Further reductions in the depth of topsoil in such instances will have a predictable effect on the yields. The value of topsoil in terms of crop yields will vary, depending on the type of subsoil and the parent material. Then there are some soils, especially in the Southeastern States, in which the subsoil has a better capacity for holding moisture and fertilizer than has the present topsoil; in such cases the loss of topsoil may even increase productivity. But these cases are the exception. Most of the results of experimental studies in the Northern States indicate that crop yields decrease as topsoil is lost and that the decrease in yields per inch of topsoil loss usually increases as additional inches of topsoil are eroded away.

Results of crop-yield studies on about 40 soils in 10 Northern States show a surprising similarity in the effect on yields resulting from the loss of an inch of topsoil in the case of soils on which topsoil is of comparable depth. For such soils, it appears that the base yield is established by the nutrient level in the parent materials. Each inch of topsoil adds to the expected yield. On many soils, it appears that treatment, management, and physical condition, affect base yields but do not eliminate differences due to the depth of topsoil. Therefore, although treatment after erosion of topsoil may restore or somewhat increase the present level of yields, similar treatment if it had been given before the erosion took place might have given an equal increase in yield.

Variations in yields with different depths of topsoil on the same soil type thus indicate the decrease in physical crop production that is associated with loss of topsoil by erosion on that depth of topsoil and on that particular soil type.

Unfortunately, most of the available data are very limited. Much is for one or two crop years only. Methods of measurement used in different experiments have not been comparable and the years studied have not always been the same. Results of any one experiment may be inconclusive. There is a wide variation in the soil types represented but most of these soils were farmed under somewhat similar conditions. Not all soils even of one type follow exactly the same pattern under loss of topsoil. But when the results of all of these experimental studies are brought together, an over-all pattern becomes evident. There is considerable variation but the results are consistent, whether the soil type studied was in New York, Oregon, Missouri, or some other State.

On the average, these data indicate that for this group of soils an inch of topsoil had an average productive capacity (depending on the depth of topsoil) of from 2.0 to 6 bushels of corn per acre-inch of topsoil; 1.5 to 5.5 bushels for oats; from 0.7 to 3.0 bushels for wheat; and 5 to 10 bushels for potatoes. Limited data for other crops indicate that the loss of an inch (in depth) of topsoil where

[1] Topsoil, as the term is used here, refers to that upper layer of soil, formed over a long period by nature, that normally contains most of the humus or organic matter.

the depth averages 8 inches reduces the yields about 2 bushels per acre for barley, 1.6 bushels for soybeans, 7 bushels for potatoes, and between 0.1 and 0.2 ton for hay. It must be recognized here that all of these data are for certain soils and areas in the Northern States which have similar climatic conditions; they would not necessarily be the same for soils farmed under other sets of conditions. The applicability of these data is limited to the soil types covered in these sample fields until further work indicates whether they may be applied more generally.

## Generalized Results of Studies

So far, studies of the effect on yields from loss of topsoil have been made on only a limited number of soil types. For those types, if farmed under comparable conditions, and if climate and rainfall are similar or are not limiting factors, two facts may be noted: (1) The same number of inches of topsoil had about the same productive capacity regardless of the parent material and (2) improved management or treatment could maintain or increase the yields, but yields were lower on the fields on which a part of the topsoil had been lost than on uneroded fields that received similar management and treatment. Apparently treatment and improved management practices often increase yields by about the same amount on both eroded and uneroded land. On such soils as are comparable to those for which data are available, the difference in yield attributable to loss of topsoil would therefore be about as indicated.

Three types of experimental data available for testing seem to support these conclusions.

(1) Agricultural experiment stations in Missouri, Ohio, New Jersey, New York, and Canada have plot data giving yield figures for fields (a) from which the topsoil has been removed, (b) on which the natural thickness of topsoil remains, and (c) on which topsoil has been increased. Figures showing differences in yields for different depths of topsoil are available from these stations.

(2) A flood-control survey for Ohio and projects of agricultural experiment stations in Indiana, Missouri, Oregon, and possibly other States, have gathered information regarding yields on different parts of control fields with various depths or thickness of topsoil. Often these results are from the university farms or other tracts for which a long-time cropping history is available.

(3) Studies have established relationships between crop yield and depth or thickness of topsoil through trials or scatter tests of yields by depth of topsoil; usually these studies have been made on scattered farms. Such data are known to be available for farms in Illinois, Wisconsin, Minnesota, New Jersey, New York, and Iowa.[2] The studies are limited to a few soil types and for 1 year, and were made on farms that had a considerable variety in regard to management and to soil treatment.

Some variations in yield per inch of topsoil were caused by differences in the stand of the crop obtained. Best stands are usually obtained on the deeper topsoil. When sampling procedures that correct differences in stand are used, slighter effects from loss of topsoil were indicated. Therefore, part of the difference in yield may be due to the better stands obtained where topsoil is deep.

## Effect of Topsoil Depth

When topsoil was removed from one part of a field and deposited on another part of the same field, there was a lower total yield for the field even if no soil were removed entirely from the field. When water deposited topsoil to the depth of an inch usually less was added to the productive ability of the land on which it was deposited than the decrease caused on the land from which it was removed. The lowered producing ability of eroded and then redeposited topsoil was primarily the result of increasing the depth of topsoil. The depth of topsoil when erosion has occurred is usually less than where deposition occurs. For the fields and soils considered, an inch of topsoil when deposited on topsoil that had a depth of 12 to 14 inches, added only about half as much to the yield as was lost by the erosion of an inch of topsoil where the depth of topsoil was less than 4 inches. Evidently, there is a decreasing increment in yield as topsoil increases in depth; an additional inch of topsoil is worth much less on a 12-inch soil than on a 5-inch soil.

For the plots about which data were available, the variations in yields per inch of topsoil attribut-

[2] For similar data for the Southern Piedmont, see William E. Adams, Journal of Soil and Water Conservation, July 1949, p. 130.

TABLE 1.—*Indicated trend of crop-yield response to depth of topsoil, for selected soils, North Central States*

| Depth of topsoil (inches) | Corn [1] | | Oats [2] | | Wheat [2] | |
|---|---|---|---|---|---|---|
| | Yield per acre | Yield per additional inch of topsoil | Yield per acre | Yield per additional inch of topsoil | Yield per acre | Yield per additional inch of topsoil |
| | *Bushels* | *Bushels* | *Bushels* | *Bushels* | *Bushels* | *Bushels* |
| 0 | 30 | ---------- | 44 | ---------- | 15.0 | ---------- |
| 2 | 41 | 5.5 | 55 | 5.5 | 21.0 | 3.0 |
| 4 | 51 | 5.0 | 65 | 5.0 | 26.0 | 2.5 |
| 6 | 60 | 4.5 | 73 | 4.0 | 29.5 | 1.8 |
| 8 | 68 | 4.0 | 79 | 3.0 | 31.5 | 1.0 |
| 10 | 75 | 3.5 | 83 | 2.0 | 33.0 | .7 |
| 12 | 81 | 3.0 | 86 | 1.5 | ---------- | ---------- |
| Average for 8 inches of topsoil | 48 | 4.8 | 79 | 4.4 | 31.5 | 1.0 |

[1] Data are calculated on the basis of averages of plotted data from individual experiment-station or field-study results. Data cover part or all of the period 1937–47. Yields of corn are primarily from Missouri, Indiana, and Iowa.

[2] Data for oats were primarily from Wisconsin and Minnesota; data for wheat largely from Ohio. Wheat-yield data also check closely with comparable data from Oregon.

able to variations in depths of topsoil within one soil type were greater than the differences between two or more soil types that had similar topsoil depths. In other words, on those soils from which data were available, an inch of topsoil seemed to have about the same value regardless of the type of soil material; and increases in yield above those expected on the subsoil appeared to vary directly with the depth of the topsoil. From the limited experimental data available, the expected effect of variations in depth of topsoil for the soil types included will probably resemble the averages shown in table 1.

## Estimating Effects of Erosion

If it can be assumed that differences in depth of topsoil have about the same effect on crop yields throughout a soil-type area, then these fragmentary data for various crops from many locations can be used to estimate the expected effect for crops in a farm rotation. If this assumption is safe, a farmer can estimate how much his yields will go down if he permits erosion to continue unchecked; and a soil scientist can estimate the rate of loss of topsoil on the basis of cultural practices, soil type, rainfall, and slope. Taken together, these estimates will indicate the rate of decline in yields to be expected with and without any particular degree or type of erosion-control program.

As it takes several years for an inch of topsoil to be washed away even on the most erodible land, the effects of erosion are usually measurable only when a relatively long period is considered. Estimates made by the Soil Conservation Service indicate that the average annual loss of soil in Iowa is about 23 tons per acre; in Illinois nearly 10 tons; and in Ohio about 6 tons. A major part of this eroded soil is topsoil which is lost mostly through sheet erosion. Complete elimination of soil movement is not possible on land that is cultivated, but if the methods of cultivation and the types of cropping systems and rotations are varied, far different rates of erosion will occur than if the same soil always receives the same treatment and grows the same crops.

Practical erosion control means the adoption of those farm practices which will allow a farmer to continue profitable operations and at the same time conserve his soil. It must provide for a reduction in erosion to as great extent as is consistent with the type of farming that farmers in the area will follow. In most areas the reduction of the average annual loss of soil to 2 to 5 tons per acre is considered an attainable and satisfactory goal. In areas in which annual losses currently exceed 15 tons per acre, a reduction to a 2- to 5-ton annual loss would be a major accomplishment.

Where the rate of topsoil loss can be reduced by a known amount and the effect of the loss of an inch of topsoil can be estimated from studies of yield versus topsoil depth, a farmer may rather accurately estimate how much the control of the erosion will affect his yields. For example, if the present annual loss of soil averages 12 tons per acre and if changes in cultural methods would reduce this to 2 tons annually, the loss of topsoil will be reduced by the equivalent of 1 inch, every 15 years, below the rate that would proceed without such conservation practices. Thus, using the general averages indicated earlier, yields of corn without erosion control might be expected to fall about 1 bushel every 4 years or about 4 bushels in 15 years. Yields of other crops might be estimated in the same way.

## Effect on Net Income

As reductions in fertility mean little or no reduction in costs of raising the crop, almost the entire reduction in crop yields is a reduction in net income. Thus, if the yield of corn on a farm now averages 40 bushels per acre, and without erosion control may fall, in 15 years, to 35 bushels per acre, the value of erosion control is considerable. Assume for example that it costs $30 per acre to raise a 40-bushel crop of corn on this farm. Assume the corn is worth $1 per bushel at the farm. Net income is thus $10 per acre on this corn land. If erosion is allowed to continue, a yield of 35 bushels at the same unit price would give net returns of only $5 per acre or half those now realized.

But if erosion-control measures were instituted that were 80 percent effective in preventing loss of topsoil, the yield of corn would fall about 1 bushel per acre, instead of 5 bushels. Net income from this corn land at the end of 15 years would be $9 per acre, instead of the $5 which might be expected without erosion control. Land-building practices here, coupled with erosion control, might well result in future yields equal to or exceeding the present yields on such land.

## What Can a Farmer Afford?

How much can a farmer afford to invest to prevent or reduce erosion? For any soils for which these relationships between yields and the depth of topsoil are applicable, the effect of erosion on yields of individual crops gives clues, but does not give the entire answer.[3] If the Government mak[es] payments that represent the additional social o[r] national value associated with erosion control, then such payments may be added to the expenditure that a farmer can justifiably make to prevent erosion. Also changes in rotations are often an essential element in an erosion-control program. These changes frequently include planting a lower proportion of the cropland to the more profitable crops. A complete analysis of the effect of erosion-control practices on farm income may be necessary if the over-all effect of erosion-control practices is to be calculated. So far, very little attention has been given to this part of the problem.

But assume that (with changes in rotations, conservation practices, etc., all taken into consideration) this mythical farm with conservation farming will return a net income of $1,700 at the end of 20 years as compared with $1,500 per year if there is no change from present practices which do not include erosion control measures.

This still does not give the entire story a farmer needs. With conservation, the level of income may be stabilized; without, it may go further down. Thus, while the effect of loss of topsoil on yields of crops may give a clue to the value o[f] erosion-control practices, it is still not a simp[le] job to estimate with accuracy how much a farmer can afford to pay to avoid a loss of his soil.

A farmer must consider the costs of instituting erosion-control measures, the effect of necessary changes in rotations and farming practices on the net income from the land, and the probable trend in expected net income if erosion is not controlled. To make an intelligent appraisal of these conditions, he will need the help of the soil scientists, the conservationists, and the economists, to work out the many interrelationships already suggested. But if the relation between the loss of topsoil and the yields of crops proves to be as direct as these fragmentary results indicate, this procedure will offer promise as an aid in evaluating the effect of conservation practices on any given farm.

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[3] If future experiments indicate other relationships between yields and depth of topsoil on other soils, the new data may be substituted without changing the procedure. No comparable data were found for southern crops. With different assumptions on yields per inch of topsoil for other soil types, the same procedure would apply.