The Influence of Technological Progress on the Long Run Farm Level Economics of Soil Conservation
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Theoretical Crop Yield Projection Model
Crop Yield-Topsoil Depth Relationship

The justification for soil conservation on agricultural productivity grounds rests on the decline in crop yields as topsoil is lost when other factors are constant. Crop yield response functions estimated by a number of researchers from field observations on yields and topsoil depths have repeatedly confirmed this relationship (Rosenberry et al.; Pawson et al.; Wetter; Harker et al.; Taylor). Ideally, a crop response function could be expressed as:

\[ Y = f(D, Q, M, W, E) \] (1)

where:
- \( Y \) is crop yield per acre in time era \( E \);
- \( D \) is topsoil depth;
- \( Q \) is a vector of soil chemistry and structure components (excluding topsoil depth) and land physical topographic features that affect yield;
- \( M \), a vector of management factors;
- \( W \), a vector of weather, climatic, pest, and other factors; and
- \( E \), the time era (year or years) during which the function was estimated. \( E \) serves as a proxy for the level of general agricultural technology.

Ideally, all of these variables would be included as exogenous variables. Since data are not available to estimate this complete model, most researchers have estimated the yield response to topsoil depth alone, taking all the other variables as given.

Estimated response functions have generally revealed that both winter wheat and dry pea yields in the Palouse are cut by more than 50 percent by the loss of all topsoil (Pawson et al.; Taylor; Harker et al.). On deep topsoils, yields asymptotically approach a maximum yield as the effective depth of crop root penetration is exceeded. From a long run modeling perspective the most important feature of the crop yield-topsoil depth response functions from the Palouse region is their nonlinearity. Yield declines are relatively modest for erosion from deep soils, but
yield penalties for uncontrolled erosion become increasingly severe as the topsoil mantle grows shallower. As erosion progresses, inferior subsoil properties increasingly restrict crop yields.

**Theoretical Implications of the Yield Projection Model**

Figure 1 illustrates for a pair of hypothetical examples the joint influence of the nonlinear yield function and the multiplicative technology shift on the projected yield benefits from soil conservation. Response function $Y_0$ could represent an estimated relationship between winter wheat yields and topsoil depths during the 1970's. $Y_n$ would then represent the projected yield-topsoil depth relationship prevailing at a future period, $n$, after several years of further progress in wheat breeding, pest control, and other technical improvements. Let $D_6$ be initial topsoil depth for a deep topsoil location and $D_3$ be the initial topsoil depth for a relatively shallow topsoil location. The use of a soil-conserving system such as minimum till is projected to result in the relatively modest topsoil loss of $(D_6 - D_5) = (D_3 - D_2)$ over the period from $t = 0$ to $t = n$. Use of a more erosive heavy till system leads to the larger topsoil loss of $(D_6 - D_4) = (D_3 - D_1)$ over the same span of years. The arrows $AB$ and $AC$ project future yield trends under minimum till and heavy till, respectively, assuming an initial generous endowment of topsoil in excess of two feet as existed in much of the eastern Washington-northern Idaho Palouse when its prairies were first plowed in the 1880’s. The arrows $DE$ and $DF$ compare the yields for minimum till and heavy till, respectively, over the same time span assuming, an initially thinner topsoil layer, or one reduced to this depth by years of intensive farming. The available evidence strongly suggests that the process summarized in Figure 1, with more technical progress on deeper topsoils, is an accurate description of the relationship existing for the Palouse region (Kaiser; Young et al.). Two conclusions with practical and policy importance emerge from this conceptualization of the interaction between technical progress and topsoil erosion: (1) During the early years of intensive farming of fertile but erosion prone steep slopes, farmers and policymakers may be lulled into a false sense of security by strong growth in yields in spite of heavy erosion (arrow $AC$ in Figure 1). This yield growth is promoted by general agricultural technical progress acting on a literal "cushion" of deep topsoil. (2) Once topsoil levels reach depths of one foot or less (based on Palouse conditions), continued use of erosive farming practices can lead to a decline in yields (arrow $DF$ in Figure 1) despite continuing technical progress. At this stage, the future
yield payoff to soil conservation is large (yield at E minus yield at F in Figure 1). On hilltops and
other areas with relatively shallow natural topsoils, the high payoff from soil conservation can
exist from the time intensive farming begins.

The preceding discussion demonstrates that an inadequate portrayal of the interaction between
soil erosion and general technological improvements can result in underestimation of the payoff
from soil conservation. Farmers who fail to protect their topsoil in the near term are making
themselves vulnerable to a potential double penalty in the future. First, future yields are directly
reduced because lower topsoils produce lower yields at a given level of technology. Second, and
equally important, there is a reduction in the capacity to benefit from future improvements in
agricultural technology because these improvements have less impact on eroded soils.

![Diagram of Yield-Topsoil Depth and Technological Progress Interaction](image)

**Figure 1.** Yield-Topsoil Depth and Technological Progress Interaction.