Soil Treatment	**Runoff from Land as Percent of Rainfall on Land** (percent)	**Soil Lost** (tons per hectare-year)	**Erosion Rate** (centimeters per 100 years)
No crop, but tilled regularly	31	114	71
Corn grown continuously	29	49	34
Wheat grown continuously	24	25	17
Crop rotation (corn, wheat, clover)	14	7.0	4.6
Bluegrass sod grown continuously	12	0.85	0.6

Figure 4-56 Soil losses due to water erosion under different soil treatments
Source: Miller and Krusekopf 1932.

The average life of land ALL decreases significantly when the protective cover of grass and forest is replaced by an intensively cultivated monoculture. For example, intertilled crops such as corn and potatoes tremendously augment water erosion. Oats and wheat, which are species of grass, offer a better obstruction to surface wash, but their soil-holding capability is still lower than that of the original soil protective agencies. Figure 4-56 gives the losses due to water erosion on a shelly, silt, loam soil at a Missouri agricultural station.The data indicate that cropped land may be denuded at a rate of 0.3 meter or more per century, that is, up to one hundred times faster than the "natural erosion rate."

We represented this acceleration of erosion under conditions of intensive cultivation by making the average life of land ALL a variable that is dependent on cultivation intensity. The average life of land normal ALLN is multiplied by a modifier called the land life multiplier from yield LLMY, which can reduce the average life of land as intensity, and therefore yield, increases.

```
ALL.K=ALLN*LLMY.K                                   112, A
ALLN=6000                                           112.1, C
    ALL    - AVERAGE LIFE OF LAND (YEARS)
    ALLN   - AVERAGE LIFE OF LAND NORMAL (YEARS)
    LLMY   - LAND LIFE MULTIPLIER FROM YIELD
               (DIMENSIONLESS)
```

Land Life Multiplier from Yield LLMY As already mentioned in the discussion of the causal loops of the agriculture sector, we assumed that there is usually an underallocation of resources for controlling erosion. This underallocation occurs for two reasons:

1. The costs of erosion control are immediate, but the benefits are not usually realized for several generations.
2. It is very difficult to monitor processes as slow as land erosion and therefore difficult to judge how much effort should be devoted to controlling the process.

We also assumed that erosion occurs more quickly as the vegetation departs further from natural mixed ecological systems and toward machine-cultivated, high-yield monoculture. Therefore, more erosion control is needed when cultivation is more intense but, for the two reasons already cited, we assumed that that need is not immediately recognized or satisfied. These two assumptions led us to the conclusion that more intensive use of the soil will lead to an erosion rate that is faster than the "normal" rate, although still very slow in terms of human generations.

It would be most desirable to link the erosion rate with intensive cropping practices through some objective index of the extent to which each modern agricultural development alters the soil structure and its exposure to eroding agents. Unfortunately, such an index does not exist, nor does there seem to be enough knowledge about erosion rates to create one. In the absence of a better index of the disturbance of natural soil ecology, we made the (oversimplified) assumption that the land yield, an indirect measure of cropping intensity, provides some indication of the probable additional exposure of soil to erosion.*

Over the past, there has been a correlation between the land yield and the disruptive interference needed to bring forth unnatural amounts of food from the land, but the relation is certainly not absolute. If society desires to do so, it can probably avoid the increased erosion rates, even while obtaining high yields, by setting aside sufficient resources to accomplish this task. Future agricultural models should formally recognize and incorporate this possibility. The extent of erosion in the world does seem to indicate, however, that human societies in recent history have not felt sufficient responsibility for the future to expend much serious effort on soil conservation.

As shown in Figure 4-57 we hypothesized the following relationship between the land life multiplier from yield LLMY and land yield LY:

```
LLMY.K=CLIP(LLMY2.K,LLMY1.K,TIME.K,PYEAR)           113, A
    LLMY   - LAND LIFE MULTIPLIER FROM YIELD
               (DIMENSIONLESS)
    CLIP   - A FUNCTION SWITCHED DURING THE RUN
    LLMY2  - LLMY, VALUE AFTER TIME=PYEAR
               (DIMENSIONLESS)
    LLMY1  - LLMY, VALUE BEFORE TIME=PYEAR
               (DIMENSIONLESS)
    TIME   - CURRENT TIME IN THE SIMULATION RUN
    PYEAR  - YEAR NEW POLICY IS IMPLEMENTED (YEAR)

LLMY1.K=TABHL(LLMY1T,LY.K/ILF,0,9,1)                114, A
LLMY1T=1.2/1/.63/.36/.16/.055/.04/.025/.015/.01     114.1, T
    LLMY1  - LLMY, VALUE BEFORE TIME=PYEAR
               (DIMENSIONLESS)
    TABHL  - A FUNCTION WITH VALUES SPECIFIED BY A TABLE
    LLMY1T - LLMY1 TABLE
    LY     - LAND YIELD (VEGETABLE-EQUIVALENT KILOGRAMS/
               HECTARE-YEAR)
    ILF    - INHERENT LAND FERTILITY (VEGETABLE-
               EQUIVALENT KILOGRAMS/HECTARE-YEAR)
```

*An undesirable side effect of this assumption is the following: in World3, higher levels of pollution lead to lower land yield. We also assumed that higher land yields lead to faster erosion. Hence in World3 an increase in the level of air pollution, among other things, leads to a *reduction* of the land erosion rate. We accepted this anomaly only because the coupling between air pollution and the erosion rate is rather weak. It might have been better to make the land life multiplier depend on agricultural inputs per hectare AIPH rather than on land yield LY.