Loop 2: Food from Investment in Agricultural Inputs

The agricultural production function in World3 contains just two basic inputs: arable land and capital. In the last subsection we described the equations representing the generation of arable land by investment of a fraction of industrial output in land development. We now discuss the equations representing a parallel process: the investment in "agricultural inputs," which we define as manufactured capital goods intended to increase land yield (for example, fertilizers, pesticides, farm machinery, and irrigation systems). This second process may well be the primary means of increasing the world's food output in the future.

> . . . IWP favours intensification of land and water use over the addition of new land as the major policy, in most of the regions studied. For some countries, where land reserves are limited, such as India or the countries in N. W. Africa, there is little choice with respect to intensification, but even in those countries *where a choice was permitted by unutilized land resources, intensification was chosen as the main component of increases in agricultural production.* [FAO 1970*a*, vol. 1, p. 51]

Agricultural Inputs AI Every year the world's farmers invest in a certain volume of agricultural inputs. We call this yearly investment the current agricultural inputs CAI (measured in dollars per year); it is equal to the part of the total agricultural investment TAI that is not allocated to land development.

```
CAI.K=TAI.K*(1-FIALD.K)                                    98, A
   CAI    - CURRENT AGRICULTURAL INPUTS (DOLLARS/YEAR)
   TAI    - TOTAL AGRICULTURAL INVESTMENT (DOLLARS/
            YEAR)
   FIALD  - FRACTION OF INPUTS ALLOCATED TO LAND
            DEVELOPMENT (DIMENSIONLESS)
```

The majority of these inputs are short-lived, normally lasting for only one growing season (fertilizer, seed, pesticides, operating costs for machinery, housing, and irrigation systems). The rest have a lifetime of several years (acquisition costs for machinery and farm buildings). On the average, agricultural inputs AI are useful for somewhat more than a year. Consequently, the effective amount of agricultural inputs AI available at any time to increase the actual food output depends not only on the current agricultural inputs CAI but also to some extent on past values of CAI. We made the assumption that the effective agricultural inputs AI can be approximated by a first-order exponential smoothing of current agricultural inputs CAI with a time constant (the average life of agricultural inputs ALAI) equal to 2 years.

```
AI.K=SMOOTH(CAI.K,ALAI.K)                                  99, A
AI=5E9                                                     99.1, N
   AI     - AGRICULTURAL INPUTS (DOLLARS/YEAR)
   SMOOTH - FIRST-ORDER EXPONENTIAL INFORMATION DELAY
   CAI    - CURRENT AGRICULTURAL INPUTS (DOLLARS/YEAR)
   ALAI   - AVERAGE LIFETIME OF AGRICULTURAL INPUTS
            (YEARS)
```



```
ALAI.K=CLIP(ALAI2,ALAI1,TIME.K,PYEAR)                      100, A
ALAI1=2                                                    100.1, C
ALAI2=2                                                    100.2, C
   ALAI   - AVERAGE LIFETIME OF AGRICULTURAL INPUTS
            (YEARS)
   CLIP   - A FUNCTION SWITCHED DURING THE RUN
   ALAI2  - ALAI, VALUE AFTER TIME=PYEAR (YEARS)
   ALAI1  - ALAI, VALUE BEFORE TIME=PYEAR (YEARS)
   TIME   - CURRENT TIME IN THE SIMULATION RUN
   PYEAR  - YEAR NEW POLICY IS IMPLEMENTED (YEAR)
```

Since to our knowledge no estimate exists of the 1900 value of agricultural inputs AI for the entire world, we had to rely on a very rough assessment of this value. The 1900 level of arable land AL was 0.9 billion hectares (see the discussion under loop 1). The agricultural inputs per hectare AIPH in 1900 must have been relatively small, given that most of the modern inputs had not yet been invented or were only rarely available. Figure 4-30 indicates how small the total use of such inputs was in the United States in 1910 compared with 1960, although the land base over which they were used had changed only slightly. In World3 we assumed that the global average AIPH in 1900 was about one-half of what it is today in the nonindustrialized areas of the world, or about 5 dollars per hectare-year (Figure-32). Thus the 1900 level of agricultural inputs AI (=AIPH times AL) becomes roughly 5×10^9 dollars per year (approximately equal to 5 dollars per hectare-year times 0.9×10^9 hectares). Although this estimate is probably correct only to within a factor of two, the possible error is not very important, since the feedback loops in the agriculture sector quickly adjust the agricultural inputs and hence the food production to the level required by the indicated food per capita IFPC table shown in Figure 4-26.

Resource Category	1910	1920	1930	1940	1950	1960
Farm labor	135	143	137	122	90	62
Machinery and power	28	44	55	58	118	142
Farm buildings	99	116	111	98	106	128
Fertilizer and lime	20	28	36	48	118	192
Tractors	—	9	32	55	119	133
Combines	—	1	12	37	137	205
Cornpickers	—	—	17	36	151	251
Feed, seed, and livestock purchased	22	32	37	63	101	149
Miscellaneous capital operating items	71	85	96	93	108	138
Cropland	87	95	103	100	100	92

Figure 4-30 Changing patterns of input use in U.S. agriculture, 1910–1960
Note: These entries represent an index of major categories of inputs (1947–1949=100).
Source: Heady and Tweeten 1963, p. 15.