starvation following deterioration of the soils in the area. The Mayan society was based on slash-and-burn agriculture, and the reduction of land fertility may have occurred when population pressure was such that it was no longer possible to let the land lie fallow for the required 10–15 years between each cultivation period. It may have become necessary to shorten the period of fallow (in terms of World3 to reduce the resources allocated to land maintenance), with a resulting rapid reduction of land fertility. The dynamics of population pressure in a slash-and-burn society have been investigated by Shantzis and Behrens (1973). Modern-day examples of such short-sighted behavior under extreme pressure from food shortage have been cited by Allan (1965) and by Kunstadter (1972).

We chose to include a representation of this type of behavior in World3, although the resulting structure affects the model's behavior only in the few cases where prolonged food shortages occur. We assumed in World3 that very low ratios of average food per capita FPC to subsistence food per capita SFPC must be reached and sustained for several years before the global aggregate food production system is forced to abandon the practice of land fertility maintenance. The delay of several years is intended to represent the fact that constraints on trade and distributional inequalities act to preserve some land maintenance. But in a situation of prolonged food shortage, we assumed that land maintenance becomes of secondary importance compared with survival and is partially abandoned. Under these conditions societies may return fallow land to cultivation too frequently, build irrigation plants without proper (expensive) drainage systems, feed crop residues to animals rather than return them to compost, and even in extremes eat the grain that should be reserved for seed.

These assumptions are represented in the model by the relation shown in Figure 4-68. This figure relates the fraction of agricultural inputs allocated to land maintenance FALM to the perceived food ratio PFR, the latter being an averaged value of the ratio of actual to subsistence food per capita FPC/SFPC. The subsistence amount of food was set equal to 230 vegetable-equivalent kilograms per person-year (see the discussion under loop 2 in this section). We assumed that the food shortages must be extreme for a two-year period, as defined by the food shortage perception delay FSPD, before the allocation of capital to land maintenance changes significantly. If PFR is 1.0, implying just subsistence food per capita, we assumed that 4 percent of agricultural inputs per hectare AIPH would be invested each year in land maintenance (enough to reduce the land fertility regeneration time LFRT from 20 years to 8 years).

```
FALM.K=TABHL(FALMT,PFR.K,0,4,1)                          126, A
FALMT=0/.04/.07/.09/.1                                   126.1, T
    FALM   - FRACTION OF INPUTS ALLOCATED TO LAND
                MAINTENANCE (DIMENSIONLESS)
    TABHL  - A FUNCTION WITH VALUES SPECIFIED BY A TABLE
    FALMT  - FALM TABLE
    PFR    - PERCEIVED FOOD RATIO (DIMENSIONLESS)

FR.K=FPC.K/SFPC                                          127, A
SFPC=230                                                 127.1, C
    FR     - FOOD RATIO (DIMENSIONLESS)
    FPC    - FOOD PER CAPITA (VEGETABLE-EQUIVALENT
                KILOGRAMS/PERSON-YEAR)
    SFPC   - SUBSISTENCE FOOD PER CAPITA (VEGETABLE-
                EQUIVALENT KILOGRAMS/PERSON-YEAR)
```



```
PFR.K=SMOOTH(FR.K,FSPD)                                  128, A
PFR=1                                                    128.1, N
FSPD=2                                                   128.2, C
    PFR    - PERCEIVED FOOD RATIO (DIMENSIONLESS)
    SMOOTH - FIRST-ORDER EXPONENTIAL INFORMATION DELAY
    FR     - FOOD RATIO (DIMENSIONLESS)
    FSPD   - FOOD SHORTAGE PERCEPTION DELAY (YEARS)
```

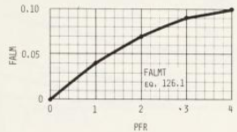

Figure 4-68 Fraction allocated to land maintenance table

4.6 SIMULATION RUNS

This section describes the dynamic behavior of the agriculture sector as it is driven by exogenously determined inputs that represent possible patterns of influence from the other sectors of World3. These exogenous inputs are population POP, industrial output IO, and the index of persistent pollution PPOLX. The equations that generate these exogenous inputs are defined in the program listing in the appendix to this chapter. To promote a basic understanding of the possible behavior modes of the agriculture sector, the inputs are formulated as exponentially increasing functions in the first four parts of this section. The final part shows the behavior of the sector when, after a period of growth, the driving factors are held constant at different values. The behavior of the agriculture sector when it is embedded in the complete world model is discussed in Chapter 7.

Historical Run

Run 4-1 (Figure 4-69) shows the behavior of the agriculture sector given initial values characteristic of the year 1900 and run to 1970. The four plots show the response of different variables during the same simulation. This run approximately reproduces world aggregate historical data for the period 1900–1970 as shown in section 4.2. The model generates reasonable 1970 values for arable land AL (1.4 billion hectares), development costs per hectare DCPH (1,000 dollars per hectare), agricultural inputs per hectare AIPH (40 dollars per hectare year-year) land yield LY (2,000 vegetable-equivalent kilograms per hectare-year), and food per capita FPC (500 vegetable-equivalent kilograms per person-year).

The growth in total food production F is caused by an increase in both arable land AL and land yield LY (Run 4-1A). Land yield LY grows primarily because of the increase in agricultural inputs per hectare AIPH. The increase in yield occurs in spite of a slight decrease in land fertility LFERT, the inherent capability of the land to produce food without additional agricultural inputs.