appreciably reduced only under the most extreme conditions (very high levels of contamination of the soil and no attempts at enhancing the regenerative processes). We also assumed that the soil fertility does not keep on falling under increased degradative influences; it simply drops to a new, lower equilibrium level.

Land Fertility Regeneration LFR The rate at which land fertility is regenerated LFR (measured in vegetable-equivalent kilograms per hectare-year-year) is assumed to be proportional to the difference between current and inherent (maximum) land fertility. The constant of proportionality is the inverse of the time constant of the regeneration process, which we called the land fertility regeneration time LFRT.

```
LFR.KL=(ILF-LFERT.K)/LFRT.K                             124, R
ILF=600                                                 124.1, C
    LFR    - LAND FERTILITY REGENERATION (VEGETABLE-
               EQUIVALENT KILOGRAMS/HECTARE-YEAR-YEAR)
    ILF    - INHERENT LAND FERTILITY (VEGETABLE-
               EQUIVALENT KILOGRAMS/HECTARE-YEAR)
    LFERT  - LAND FERTILITY (VEGETABLE-EQUIVALENT
               KILOGRAMS/HECTARE-YEAR)
    LFRT   - LAND FERTILITY REGENERATION TIME (YEARS)
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Land Fertility Regeneration Time LFRT The best data on the time necessary for the natural restoration of land fertility come from tropical areas. Such land fertility regeneration regularly occurs in the traditional slash-and-burn agricultural methods widespread in the tropics (Nye and Greenland 1960). Land is cleared by burning, which releases the nutrients formerly stored in the vegetation. Crops are then grown in the soil enriched by these nutrients. Free soil nutrients however, are rapidly lost through leaching and to a lesser extent taken up by crops; before long the land fertility is so much reduced that cultivation must move on to a newly cleared plot of land. The depleted land is allowed to return to natural forest, requiring a fallow of 10 to 20 years, before the land is again burned and new crops harvested. Figure 4-65 provides an estimate of the amount of nutrients stored in the soil and assimilated by crops in an 18-year-old forest in the Congo.

	N	P	K	Ca and Mg	
		(pounds per acre)			
Nutrients stored in:					
18-year-old secondary forest	499	65	361	502	
Total available or exchangeable nutrients in the forest soil (0–12 ins.)	≈ 2,500	17	320	89	47
Total	≈ 3,000	82	681	638	
Nutrients removed in the harvest of:					
Rice (1,000 lbs. paddy)	12	3.2	3.5	0.8	1.4
Peanuts (500 lbs. kernels)	25	2.2	2.7	0.3	0.9
Cassava (10,000 lbs.)	22	3.0	58.0	5.4	

Figure 4-65 Amount of nutrients in soil and vegetation
Source: Nye and Greenland 1960.

If the land fertility regeneration time in the tropical jungle is about 15 years, the time in colder climates must be somewhat longer, since ground cover develops and humus releases nutrients more slowly. It is likely that the regeneration time increases with the size of the exhausted land area and the degree to which the soil is impoverished when it is left to recover (Gomez-Pompa 1972). Recovery from fertility reduction due to compaction of the soil has been observed to require 4 to 15 or more years of grass coverage in Great Britain (Pilpel 1971). The recovery from imbalances in pest populations due to pesticides is probably achieved relatively quickly, although genetic changes may persist. Natural recovery from salinization may be impossible. On the basis of such observations, we assumed that a typical value for the land fertility regeneration time when only natural forces are at work is 20 years. However, this is not the time actually required for a piece of land to recover, since man can and does speed up the natural processes through artificial procedures. To represent the human enhancement of the regeneration process, the average value of 20 years is modified in World3 as follows.

Under current agricultural practices the natural regeneration process can be significantly enhanced by human efforts through the allocation of agricultural resources to land maintenance. Examples of this type of aid to natural regeneration are the restoration of nutrient levels through adding humus, draining salty areas, reforestation, planting hedges, and reducing the leaching process by mechanical means of soil control. History seems to indicate that farmers actually do care for the fertility of their land to the extent that they do not let the land fertility degrade significantly within their own lifetimes. In other words, land fertility seems to have been relatively constant in the real world at least during this century; consequently, it should also be constant in World3 over the same period.

The land fertility will remain constant in World3 only if the forces acting to degrade fertility are exactly balanced by the forces acting to regenerate fertility. Such a balance or equilibrium can occur at many different levels of land fertility, and at different regeneration and degradation rates, as long as the two rates are equal. In other words, it is possible in World3 to have a stable land fertility at high fertility or low fertility or anywhere between.

We postulated earlier that the rate of land fertility degradation LFD increases when the persistent pollution index PPOLX and land fertility LFERT increase. We also assumed that the rate of land fertility regeneration LFR increases with decreasing land fertility LFERT and with decreasing land fertility regeneration time LFRT. For given constant values of PPOLX and LFRT, one unique value of land fertility LFERT is stable, because it makes land fertility degradation LFD equal to land fertility regeneration LFR (Figure 4-66).

Here the rates of LFD and LFR are plotted against LFERT for given values of PPOLX and LFRT. Since the resulting straight lines must always cross, LFERT reaches an equilibrium value for any set of values of PPOLX and LFRT. This equilibrium fertility is always less than the inherent land fertility ILF, except when there is absolutely no pollution. The equilibrium fertility decreases when pollution increases, and it decreases when LFRT increases.