4.1 INTRODUCTION

The fundamental assumption of the agriculture sector of the world model is that the total amount of food that can be produced on the earth each year has some limit. It is well known that the allocation of more physical resources (land, water, fertilizer, and labor) to food production will increase the annual food output. However, we postulate that the physical resources that can be allocated to food production are limited: in World3 the available agricultural land is limited, the amount of fertilizer is limited by the total global industrial production capacity, and the land fertility is limited by pollution absorption mechanisms. Although technological innovations may lead to higher yields on a given land area, we postulate that there are decreasing returns to technology's ability to increase land yields by diverting other limited resource inputs to the agriculture sector.

The purpose of this chapter is threefold: to propose a structure that relates the land and capital used in agriculture to the food output obtained, to describe the mechanisms by which food output can be increased, and to identify within the chosen structure the forces that can potentially limit total annual food production. We present, in sequence, a set of real-world data illustrating the historical behavior of the elements in this sector, a set of basic concepts underlying the model formulation, the precise causal assumptions of the sector and their exposition in equation form, and simulation runs of the sector as a driven system.

4.2 HISTORICAL BEHAVIOR MODES

The most conspicuous characteristic of the world's food production system is its rather spectacular increase in total output over the last few decades (Figure 4-1). The increase is more impressive in terms of total food production than in per capita food production, since the world population has also increased greatly. The gain in total food output can probably be attributed to two factors: an increase in the cultivated land area, and an increase in the average land yield (Figure 4-2). The observed average land yield has risen sharply within the last hundred years (Figure 4-3), largely because of the advent of modern agricultural inputs such as fertilizer, pesticides, new seed, and farm machinery (Figures 4-4 and 4-5).

There are indications that the recent increases in total global food output cannot continue indefinitely. Opportunities for expanding the amount of arable land are limited (FAO 1970*a*): some arable land is taken out of cultivation for building cities, roads, and airports; some becomes unsuitable for agricultural use through erosion, laterization, or salinization. Future increases in food production may also be restricted by decreasing returns to the use of modern agricultural inputs (Figure 4-6).

Another trend may be occurring globally: land fertility may be gradually decreasing, although little direct evidence is available to support or refute this hypothesis. Here it is useful to make a distinction between land yield (the actual food output per hectare-year obtained through the use of fertilizer, pesticides, and machinery) and land fertility (the intrinsic ability of the soil to produce food without modern