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CHAPTER 5
Food Availability After Nuclear War

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5.1 INTRODUCTION

Many studies have been published describing the potential consequences of nuclear war on scales spanning local to global effects. Most of these analyses have concentrated on the immediate and short-term effects of blast, fire, and fallout. There is no doubt that a large-scale nuclear war would produce unprecedented and disastrous death and destruction from such effects. It has not been clear, however, that the consequences of nuclear war would be equally disastrous for several billion survivors in non-combatant countries. It is evident from the discussions in Chapter 4 that one of the major problems that many survivors could face is food shortages.

Food shortages during the first few years following a nuclear war could be the result of disruption of the international economy and trade, climatic stress to agricultural systems, and the associated societal disruption that would follow (Harwell, 1984; Scrimshaw, 1984). The vulnerability of the global human population to such changes must be assessed on the basis of defining the human population that could be supported by the resulting agricultural and food distribution system. Hjort (1982) and Harwell (1984) describe many of the processes that could cause decreased food availability following nuclear warfare. These problems include direct destruction of food crops and stores, radioactive contamination, uncontrollable fires, loss of fertilizers and pesticides, reduced fuel supplies, and destruction of major ports and facilities of the global food distribution network. The United States and Canada are major food exporters that would probably suffer severe and widespread destruction in a large-scale nuclear war, and probable elimination of the means and incentives to export additional food. Other exporting countries would be faced with an international economic system disrupted to such an extent that large scale food shipments might be greatly reduced.

The projected responses of agroecosystems would greatly depend on the timing and intensity of the nuclear war, and on the assumed magnitude of climatic alteration. The temperature and precipitation reduction estimates derived from climatic modelling and analysis could be sufficient to eliminate agricultural production in most of the Northern Hemisphere and much of the Southern Hemisphere for at least one year (see Volume 1 and Chapter 4, Volume 2). Even in the absence of climatic perturbations, food production might be reduced beyond the acute effects of the first year in response to disruptions in agricultural subsidies; therefore analysis of chronic effects extending several years after a war must also be included.

The amount of food in storage is a critical issue to be resolved in an analysis of the vulnerability to an acute phase agricultural disruption. This poorly measured and poorly documented quantity is not limited to storage facilities controlled by central governments. Unless there were no time lag between food harvest and consumption, there would be food stores in farms, transportation facilities, food processing plants, and other locations. Analysis of food storage, and other critical variables, is difficult on a global basis. Nuclear war impacts would be quite different for combatant Northern Hemisphere countries and non-combatant or Southern Hemisphere countries.

Because it would be difficult to examine all countries in sufficient detail,

TABLE 5.1

1983 POPULATION DATA[a]

COUNTRY	TOTAL POPULATION (10^6)	AGRICULTURAL POP. (10^6)	% AGR.
Argentina	28.0	3.4	12
Australia	15.0	0.8	5
Brazil1	31.1	47.0	36
Canada	24.9	1.1	4
China	1,033.7	591.2	57
Costa Rica	2.4	0.8	33
India	725.5	442.1	61
Indonesia	155.6	87.9	56
Japan	119.3	10.7	9
Kenya	18.6	14.1	76
Nigeria	85.2	43.0	50
Phillipines	53.2	23.2	44
U.K.	56.3	1.0	2
U.S.	234.2	4.4	2
U.S.S.R.	272.3	39.6	14
WORLD TOTAL	4,669.7	2,075.9	43

[a] Data from FAO Production Yearbook (1983).

we have concentrated on 15 representative countries (Table 5.1), selected to include a wide spectrum of population levels, agricultural productivities, and economic and social structures. These 15 countries make up about 63% of the total world population. We have also used simplified models to provide estimates of potential food impacts on an additional 120 countries. These calculations are presented to be illustrative of potential global effects, but more research needs to be done on a national basis to properly assess this problem. The results of these analyses indicate that food problems could be the single most significant contributor to human mortality following a nuclear war. This conclusion results from a consideration of the potential global-scale disruptions in societal and agricultural systems. This vulnerability is an aspect not currently a part of the understanding of nuclear war; not only are the major combatant countries in danger, but virtually the entire human population is being held hostage to the large scale use of nuclear weapons.

5.2 METHODS AND ASSUMPTIONS

5.2.1 Introduction

Calculations of food production, stores, and consumption rates were based on energetic (caloric) equivalents (Table 5.2). Energy intake is only one aspect of diet; nutritional problems other than insufficient energy might also be important following a nuclear war, but these limitations are difficult to quantify. The resistance of individuals to vitamin and food shortages depends greatly on the initial state of health and nutrition. Shifts in dietary consumption patterns are to be expected following a nuclear war, but we

TABLE 5.2

ENERGETIC EQUIVALENTS FOR MAJOR FOOD TYPES[a]

	KCAL·KG^{-1}
Cereals	3,420
Pulses (Legumes)	3,350
Cow meat and organs	2,400

[a] Data from Chatfield (1954).

assume that an average consumption rate of 2,000 kcal$\cdot$person$^{-1}\cdot$day^{-1} is necessary to sustain people with normal activity levels, based on analyses of minimum dietary requirements for humans.

The major category of interest for food impact analyses is cereal grains. Cereals make up about 70% of the total world food energy intake (Bender and Bender, 1982). Maintaining sufficient energy intake alone would not assure survival in a food crisis; it is also necessary to consider other food types, particularly when calculated food energy supplies seem sufficient. We have also included pulses (legumes) and meat in our calculations, food types more likely to be available than fruits and vegetables. Maintaining stores of starch-rich root crops and fruits and vegetables can be very difficult; post-harvest losses of these crops are often 50–80% in tropical regions (Cross, 1985).

5.2.2 Dietary Assumptions

The normal dietary consumption pattern, classified by major food types (Table 5.3), would probably be greatly altered following a large-scale nuclear war. The average caloric intake necessary to sustain human life depends on

TABLE 5.3

DIETARY COMPOSITION[a]
(KCAL$\cdot$PERSON$^{-1}\cdot$DAY^{-1})

Country	Cereals	Roots/ Tubers	Sugar/ Honey	Pulses	Nuts/ Oilseeds	Vege- tables	Fruits	Animal Products	Total[b]
Argentina	997	143	398	17	26	53	117	1,056	3,358
Australia	837	94	572	7	21	52	103	1,330	3,400
Brazil	903	243	464	164	21	18	122	415	2,521
Canada	704	128	494	22	60	63	103	1,415	3,345
China	1,547	209	41	104	62	40	8	237	2,362
Costa Rica	876	32	611	99	19	16	149	413	2,487
India	1,233	42	177	142	28	32	29	91	1,889
Indonesia	1,405	214	134	17	117	11	26	50	2,115
Kenya	1,209	197	167	149	29	14	49	234	2,141
Japan	1,312	63	269	26	127	68	62	533	2,848
Nigeria	932	680	42	75	62	25	61	80	2,219
Phillipines	1,310	121	205	10	27	18	73	221	2,128
U.K.	693	175	537	27	34	50	62	1,255	3,311
U.S.	615	111	562	29	69	64	120	1,300	3,539
U.S.S.R.	1,365	234	446	37	21	54	56	938	3,443

[a] Data from FAO food balance sheets; 1975-1977 averages.

[b] Total includes input from other sources.

a number of factors, including population age distribution, activity levels, and climate. All of these factors, as well as what food is available and can be maintained in stores, might be influenced by nuclear war. Based on inspection of FAO calculated food energy requirements (FAO, 1982a), we assume that a minimum of 2,000 $\text{kcal} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$ is necessary to sustain life for an extended period of time. For the purpose of illustrating potential food problems, we have assumed a diet of 1,500 $\text{kcal} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$ of cereals, 500 $\text{kcal} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$ of animal products, and pulse consumption rates at current levels (Table 5.3). This dietary pattern represents the largest relative changes for developed-industrialized countries. Many countries in this category would be probable combatants in a large-scale nuclear war and would suffer destruction and disruption of the energy intensive food distribution system currently supplying more than 3,000 $\text{kcal} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$.

5.2.3 Calculation Methods: Vulnerability in the Acute Phase

The climatic consequences of nuclear war include the possibility, in the acute phase, of the elimination of agricultural production in large regions of the Northern Hemisphere temperate zone, and perhaps tropical regions in both hemispheres (see Chapter 4). In such circumstances, food storage would be a critical item controlling human survival following nuclear war induced climatic disturbances. Even with minor climatic perturbations, many countries would be expected to suffer severe food shortages in the acute phase because of probable disruption or elimination of imports.

Food storage levels differ greatly among and within countries and fluctuate significantly during the course of year. Therefore, the timing of a nuclear exchange directly relates to the potential severity of food shortages. An attack immediately after the harvest period would coincide with food storage levels much higher than one immediately before the harvest period. To account for the range of food storage levels possible within a year, we calculated food supplies three ways, representing a range of food available immediately after nuclear war:

1). Carryovers only are available. This case represents the low point in food stores. Carryover levels tend to be much higher in countries that are major grain exporters or importers (Table 5.4). We have assumed that carryovers are equal to 10% of production (the mean of measured levels in India, China, and Brazil) for Costa Rica, Indonesia, Kenya, Nigeria, and the Philippines. For the United Kingdom we have assumed that carryovers are 23% of production. Pulse carryover levels were assumed to be the same fraction of production as in cereals for all countries.

TABLE 5.4

CEREAL CARRYOVERS[a]
(10^6 TONS)

COUNTRY	CEREAL PRODUCTION	CARRYOVERS	CARRYOVERS AS % PROD.
Argentina	18.47	1.1	6
Australia	16.38	5.0	31
Brazil	33.22	1.3	4
Canada	41.48	14.3	34
China	280.40	53.0	19
India	140.50	10.8	8
Japan	13.19	10.6	80
U.S.	270.00	78.1	29
U.S.S.R.	182.70	16.0	9

[a] Data from FAO (1982a); 1980 data.

2). A median case includes carryovers, a fraction of annual imports, and a fraction of a full production, weighted for the number of harvests. The equation used to calculate the median case is:

$$F_a = 0.5 \cdot (P + C) \cdot H^{-1} + C + I/12 \qquad (5.1)$$

Where:

F_a = stored food available (kcal)
P = full harvest (kcal)
H = number of harvests per year
C = Carryovers (kcal)
I = annual imports (kcal)

3). Full production, but no imports are available. Because of variations in import levels, dietary consumption rates, and animal feeding on grains, the full production calculation may indicate support of either less than or more than the current population.

It should be clearly understood that none of these sets of assumptions reflect a prediction of the specific situation after a large-scale nuclear war. Rather, these assumptions were selected to illustrate the range of vulnerability of the human population to societal and agricultural system disruptions.

The three levels of food availability are illustrated with two hypothetical countries, each with 96×10^6 tons of cereal production. In the first case (Figure 5.1), there is only one major harvest per year (typical of many temperate countries). In this situation, maximum food storage is approximated by full annual production. Assuming a monthly consumption rate of 1/12 of annual production, the median value (disregarding imports) is midway between full production and the lowest value (carryovers). In the second case (Figure 5.2), there are two principal harvests within the year, yielding a maximum storage value half of that for the single harvest situation. The median value can be calculated as $(0.5 \cdot (P + C) \cdot H^{-1})$, or midway between one full harvest and the low point. In each case, carryovers and 1/12 of annual imports are added to the calculated median value to provide a conservative estimate.

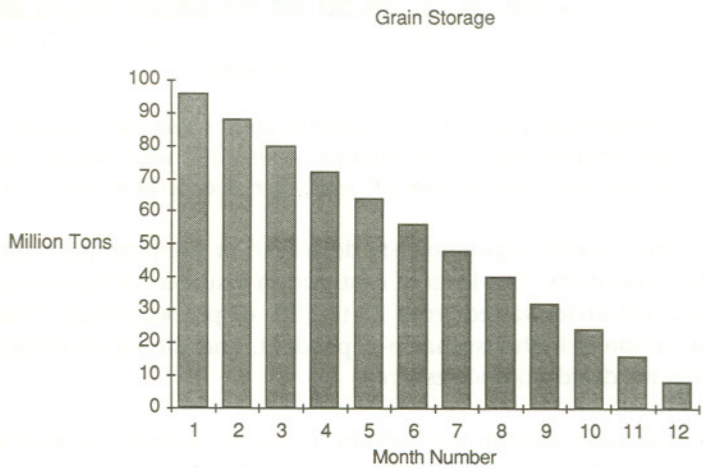

Figure 5.1 Hypothetical monthly variation of grain stores for a country with one major harvest period. Annual production (full harvest) = 96×10^6 tons; median value = 52×10^6 tons; carryover level = 8×10^6 tons

There are several major assumptions associated with the food storage calculations outlined above. The significance of some of these assumptions can be tested with sensitivity analysis, that is, varying parameter values and calculation methods and assessing the effect on the final answers. The principal assumptions, in addition to those already discussed are:

1.) No animals are fed on grain. Any feeding of animals reduces the potential support capacity to humans of grain stores and production.

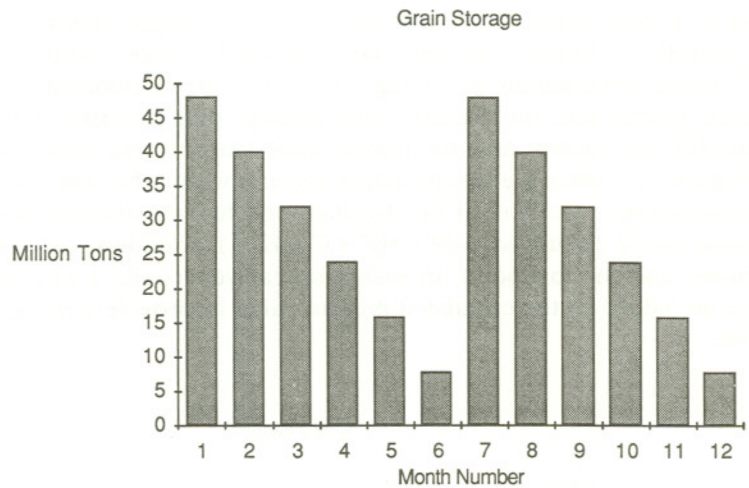

Figure 5.2 Hypothetical monthly variation of grain stores for a country with two major harvest periods. Annual production = 96×10^6 tons; one full harvest = 48×10^6 tons; median value = 26×10^6 tons; carryover level = 8×10^6 tons

2.) Food stores and population are destroyed in equal proportions in combatant countries. The level of destruction assumed in the principal combatant countries varied from 25 to 75% of pre-war levels. The level of destruction is highly scenario-dependent, and the vulnerability of food stores needs additional research.

3.) Optimal food distribution within a country occurs, so that the maximum number of people survive given the dietary assumptions. This is an highly unlikely situation following a nuclear war considering the current food maldistribution and historical analogs (Chapter 6). This assumption also requires that no food is used by those people who cannot be supported for a full year; although this assumption is very conservative, it is impossible to predict accurately the level of food hoarding, destruction, and maldistribution that would occur in any country. We have addressed this issue with sensitivity analyses of food distribution patterns, which show that more realistic assumptions would lead to significant reductions in the number of survivors.

4.) Most of the food stored would be in the form of major cereal crops. Any large stores of other foods, such as root crops and vegetables, would increase the population support capacity within a country.

5.) No predictions are ventured as to how the behavior of people as individuals and in groups would be modified by the experience of nuclear war or by the anticipation of the explosions and subsequent events.

We have used two methods of calculating human support capability of food stores in the acute phase. Assuming no agricultural production or imports for one year, the duration of support of the full surviving population is calculated, as is the total storage support in person-years.

These calculations reflect the vulnerability of the Earth's population to the loss of agricultural productivity. Based on the assumptions listed above, these values are intended to represent the physically limited, maximum number of humans that could be supported with no agricultural production. The equation used to calculate the duration of full population support is:

$$T = F_a / N \cdot D \tag{5.2}$$

Where:

T = duration (days) before food stores are depleted

F_a = total food (kcal) available (either full production, median value, or carryovers only)

N = population size

D = per capita consumption rate ($\text{kcal} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$)

A similar equation is used to calculate food storage support capacity in person-years:

$$Y = F_a / (D \cdot 365) \tag{5.3}$$

The person-year values calculated from this equation can be interpreted as the maximum number of people that could be maintained by food at the consumption rate specified (D) for one year. Of course more people could be supported at lower consumption rates, but energy shortfalls significantly below 2,000 $\text{kcal} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$ would have to be made up by other food sources. Another interpretation of this calculation could be that half the population (Y) could be supported for twice as long (two years). Given the assumption of optimal distribution noted above, it is highly unlikely that this maximum support figure could be realistically maintained in a food crisis.

For the countries (of the 15 listed in Table 1) considered to be possible combatants or targets in a major nuclear war (Australia, Canada, China, Japan, U.K., U.S.A., U.S.S.R.), the immediate effect of nuclear weapon detonations would alter food supply requirements. A critical issue concerns possible differential destruction of food stores and population. Although the distribution of food storage capacity within some countries is well known, the distribution and annual variation of actual stores is poorly known. For the combatant countries, we have assumed that food stores and population are reduced by the same fraction. In this case, food stores (assuming no agricultural production) would last as long as the pre-war levels, as in the non-combatant countries, i.e. the number of people assumed to die from the direct effects of nuclear war would have no bearing on the ultimate duration of food stores as calculated here. Calculated values for grain stores (person-years) can be easily adjusted for other assumptions. The actual vulnerability of food stores to destruction in a nuclear war, and the annual variation in stores remain an important research question.

In addition to the detailed analyses of the 15 countries (Table 5.1) outlined above, a simpler data set and model were used to assess potential food shortages in 120 other countries. Carryovers were assumed to be 10% of annual production for all countries, and only one harvest per year was assumed.

The acute phase analyses were designed to illustrate the vulnerability of each country to losses of agricultural productivity. Although the climatic analysis of Volume 1, and consideration of agricultural responses (Chapter 4, Volume 2), indicate that widespread crop losses are possible following a major nuclear war, we cannot predict the precise conditions that would be experienced in any region. If acute phase climatic disturbances permitted some agricultural production, the chronic phase analyses that follow would apply to the first post-war year also.

5.2.4 Calculation Methods: Vulnerability in the Chronic Phase

In the chronic case we assume that after the first year at least some agricultural production might be possible. Population support capacity is calculated using an equation analogous to Equation 5.3.

$$S = F_a/(D \cdot 365) \tag{5.4}$$

In this case F_a represents a sustained level of annual agricultural production, and not a storage level. The calculated value of S then, is a steady-state carrying capacity associated with the production level F_a. The actual level of production that would be realized during a chronic time-frame would be dependent on climate change and sensitivity, economic and social disruption, and losses of technological support and inputs for agriculture. These analyses are restricted to the 15 countries listed in Table 5.1 and presented as a range of possibilities, since no single most probable scenario can be identified.

The level of agricultural production and food supply in the chronic phase would depend on a number of factors. Even with 100% of pre-war production, the loss of food imports could seriously reduce population support capabilities in some countries. Climatic disturbances severe enough to impair agricultural production might occur in the chronic phase. It is not possible to predict the precise climate that would be experienced in any region during the chronic phase; therefore, we have treated this analysis as an evaluation of a range of effects from no change in climate to that of severe climatic stress (a decrease of up to 5°C in mean temperature or a 50% decrease in annual precipitation).

The potential effects of disruptions in agricultural subsidies and international trade are considered for the range of the climatic conditions postulated. The chronic phase analysis reflects the fundamental vulnerability of food supply systems to nuclear war but can only be presented as a range of possibilities.

Figure 5.3 represents the approach taken to illustrate that range of possibilities, in this case for Argentina. Six levels of production (10%, 25%, ··· 100%) are shown with their corresponding capability to support the human population, characterized as the fraction of current population. Many countries (particularly food exporters) produce more food than is necessary to feed the entire pre-war population (indicated by the bold 100% line in Figure 5.3). In Argentina, for example, the entire population could be supported by less than half of the current agricultural production. For chronic-phase impact analysis, three scenarios of agricultural production are considered, with post-war production estimates derived from a qualitative

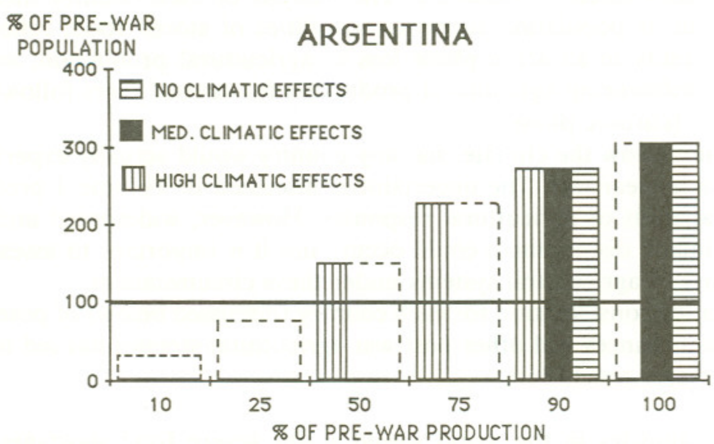

Figure 5.3 Wheat yield in Argentina. (FAO production yearbooks)

assessment of the vulnerability of the country's agriculture to climatic disturbances and losses of energy subsidies. If, for example, Argentina experienced no chronic-phase climatic disturbances, agricultural production could be maintained at near normal levels (here estimated at 90–100% of current production, Figure 5.3). If climatic disturbances also occurred (e.g., a decrease of up to 5°C in mean annual temperature, or up to a 50% decrease in precipitation), agricultural production could be further reduced (e.g., for Argentina we estimate production could decrease to levels of about 50% to 90% of pre-war production, Figure 5.3). Other analyses may more accurately refine the level of agricultural production that would occur; these may readily be viewed in terms of potential human population levels by selecting the appropriate production value from the figure. Open dashed bar graphics illustrate the production/population relationships for levels of production not considered likely to occur, based on the current estimates of possible climatic perturbations and import dependency of the country's agricultural production.

5.3 RESULTS: ANALYSIS OF 15 REPRESENTATIVE COUNTRIES

5.3.1 Introduction

A comprehensive analysis of the consequences of nuclear war requires consideration of stresses and responses on a local and regional basis, as well as on a global basis, because of the climatic, social, and economic heterogeneity that exists. We have initiated this approach using the 15 representative countries listed in Table 5.1. The analysis of each country includes a description of population support capabilities of stored food, reflecting the vulnerability to an acute phase loss of agricultural production, and of the factors influencing agricultural production for several years following a nuclear war (chronic phase).

We cannot know the climate that any country would actually experience following a nuclear war. The uncertainties discussed in Volume 1 preclude a precise analysis of agricultural responses. However, widespread and significant climatic disturbances could occur, and it is important to assess the vulnerability of agricultural systems under these circumstances.

The detailed consideration for each country (discussed below) of potential climatic disturbances and other post-war agricultural stresses has led to the following major conclusions:

1.) Most countries in the world would suffer severe food shortages and mass starvation if agricultural production were eliminated for a single growing season. Food exporting countries would normally have adequate food stores, but many of these countries could be targets of nuclear weapons. Climatic disturbances of sufficient magnitude to produce these effects might be possible over large areas of the Northern Hemisphere, and some regions of the Southern Hemisphere (see Chapter 4).

2.) If international food trade were eliminated following a nuclear war, those countries that import a large fraction of their food requirements would experience severe food shortages, even with no climatic disturbances.

3.) Agricultural production in most of the world would probably be impaired for a period of at least several years after a major nuclear war. Climatic disturbances and disruptions in world trade and production of fossil fuel, machinery, fertilizers and other agricultural subsidies could reduce the level of production maintained in the chronic phase.

Careful consideration of the assumptions should be employed when considering the descriptions of potential food and agricultural problems that follow. The climatic disturbances discussed do not represent predictions of actual post-war climates, but are discussed in order to characterize the vulnerability of each country.

5.3.2 Argentina

The impacts of a Northern Hemisphere nuclear war on Argentina would probably be much less severe than for most of the other countries analyzed. As a Southern Hemisphere temperate country, the climatic disturbances might be insignificant. If there were climatic effects, they would probably be quite variable within the country, because of the large altitudinal and latitudinal range involved. In the very severe scenarios, mean temperature decreases of a few to 15°C are possible. Additionally, significant precipitation decreases are possible. Under these conditions, mean summer temperatures (Nov.–Feb.) could be 10°C or less in most of the country. If this severe case occurred, agriculture would be significantly impaired, and only marginal crop production would be possible during the first year following a war. Animal grazing systems are an important part of agriculture in Argentina, and these pastoral regions would probably be more resistant to climatic disturbances.

Stored food shortages could become critical if production were eliminated. Although we do not have access to data on the actual monthly variation of food stores, our calculations were designed to illustrate a range of possibilities, as well as a median case. Again, we are not implying that elimination of all agriculture for one year is probable in Argentina, but we are examining the country's vulnerability to such conditions.

As a major grain exporter, Argentina has much more food on hand shortly after harvest than is necessary to feed the full population (Table 5.5). The large number of cattle (twice the human population) also provides a margin of safety. The timing of the nuclear war could be a critical factor. The level of carryovers in Argentina relative to production is unusually small for a food exporting country (Table 5.4), and if only carryovers were available, only a relatively small proportion of the population could be maintained with stores. In these circumstances, 1,000 kcal$\cdot$person$^{-1}\cdot$day^{-1} would have to be provided from other sources or mass starvation would result.

TABLE 5.5

ARGENTINA
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	1,105	586	66
Pulses	------	734	------
Beef	------	1,391	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	82 (303%)	43 (161%)	5 (18%)
Pulses	------	54 (201%)	------
Beef	------	103 (381%)	------

During the first few years following a large-scale nuclear war, Argentina, along with all other countries, would probably be affected by the disruption of the international economy and trade, even if no additional climatic impacts were experienced. Argentina is relatively independent in terms of energy production; however, coal imports represent a potential vulnerability (Table 5.6). Another potential problem area is imports of nitrogen fertilizer, which is strongly related to agricultural yields (Greenwood, 1981). Wheat yields have increased considerably in Argentina during the last 30 years (Figure 5.4), and some yield declines could be associated with fertilizer limitation in the early chronic phase. Additional climate problems are also possible in the chronic phase, if mean temperatures 5 to 10 degrees

TABLE 5.6

ARGENTINA 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	25,196	728	3
Hard Coal (1,000 MT)	515	730	142
Gasoline (1,000 MT)	5,111	-15	0
Diesel Fuel (1,000 MT)	7,569	-480	0
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	17,586	44	
Thermal	20,348	51	
Nuclear	1,870	5	
Geothermal	-------	---	
TOTAL	39,804	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	25,124	26,049	104
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	166,700	4,750	3
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	1,620	35,800	5

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

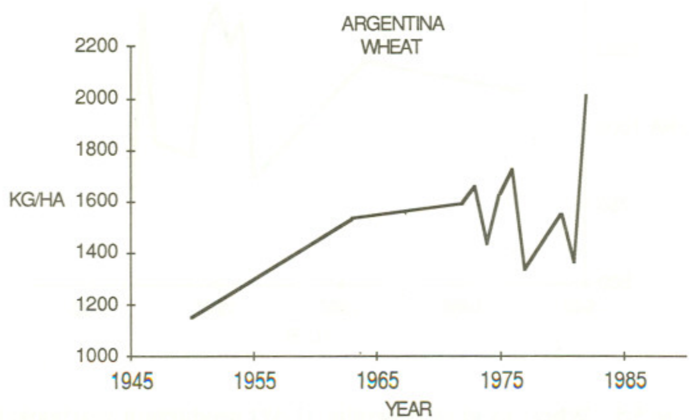

Figure 5.4 Chronic phase population support in Argentina

below normal as well as precipitation decreases of up to 50% of normal occurred.

The principal ameliorating factor for Argentina is the strength of its agricultural production system. Argentina is currently producing much more food than is needed domestically, and unless production were reduced by a factor of two, the full population should be easily supported (Figure 5.3). This figure shows a range of agricultural production and steady-state population support for three scenarios. Each case includes the energy, economic and societal disruptions that might influence agricultural production, within three levels of climatic effects.

5.3.3 Australia

Australia, as a Southern Hemisphere major food exporting country, would not be catastrophically damaged by a nuclear war fought in the Northern Hemisphere. There is a possibility, however, that Australia itself could be a target of nuclear weapons in a major war, leading to significant direct impacts (Ambio, 1982). Climatic stresses associated with nuclear war-induced atmospheric disturbances could also affect Australian agriculture (Chapter 4). Mean temperature reductions of the order of a few degrees C might lead to yield increases as a result of reduced evapo-transpiration and moisture stress, but larger decreases or freezing episodes during the growing season could cause significant crop losses. Precipitation decreases would also cause reduced crop yield in much of Australia. The potential vulnerability of

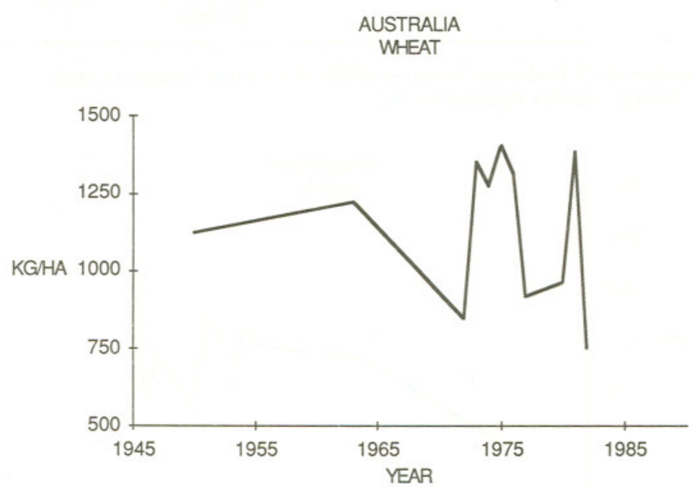

Figure 5.5 Wheat yield in Australia. (FAO production yearbooks)

Australian wheat production to climatic change is illustrated by Figure 5.5. Although Australian agriculture is energy-intensive and mechanized, there is no evidence of increased wheat yields during the last 30 years. A large fraction of the year-to-year variability of Australian crop yields (60–80%) is attributable to weather variability (Russell, 1973). Precipitation decreases of 50% would be expected to cause significant yield declines.

As a net food exporter, with large numbers of sheep and cattle, even complete elimination of agricultural production for one year would not necessarily lead to acute food shortages for the Australian population (Table 5.7). Pastoral agriculture is very important in Australia, and would be more resistant to climatic disturbances than wheat production.

TABLE 5.7

AUSTRALIA
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	1,856	1,211	566
Pulses	------	3,233	------
Beef	------	1,219	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	37 (254%)	24 (166%)	11 (78%)
Pulses	------	64 (443%)	------
Beef	------	24 (167%)	------

Nuclear weapon detonations might have significant impacts on Australian agriculture. Of course, we cannot know the actual level of mortality and destruction that would be experienced in Australia. One major variable would be the number of targets, if any, associated with urban areas. For this analysis, a more critical assumption is that food stores and population are destroyed in equal proportions, an issue that needs additional study.

The estimates of population support from food stores, assuming 50% destruction, are the same as the no-casualty scenario because the same fraction was used to reduce stores and population; however, the estimates in person-years should be doubled to calculate the carrying capacity of pre-war stores. In either case, there would potentially be enough food stored to feed the

TABLE 5.8

AUSTRALIA 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	18,700	9,000	48
Hard Coal (1,000 MT)	96,786	(-53,000)	0
Gasoline (1,000 MT)	10,500	150	1
Diesel Fuel (1,000 MT)	7,200	(-100)	0

ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL
Hydroelectric	15,000	14
Thermal	89,890	86
Nuclear	-------	---
Geothermal	-------	---
TOTAL	104,890	100

N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	206,000	52,000	25

TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	332,000	21,331	6

LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	1,700	46,544	4

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

entire surviving population for one year with no agricultural production (Table 5.7). This would be true regardless of the timing of the war.

The principal factors associated with agricultural impairment in the chronic phase are similar to those considered with the acute phase. The effects of disruption of agricultural technology and losses of energy subsidies could be significant, even in developed Southern Hemisphere nations. The international economic and trade relations of every country would probably be affected by a large-scale nuclear war. Australia is an example of a country that would seem relatively immune to nuclear war effects (if not targeted),

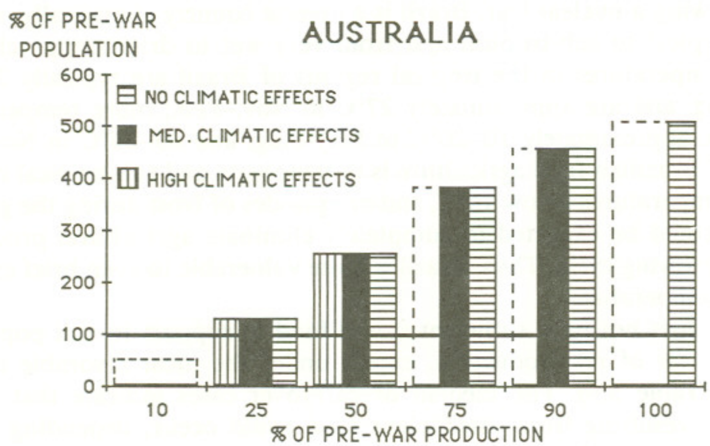

Figure 5.6 Chronic phase population support in Australia

but serious impairments of agricultural production could occur. Although Australia is a net energy exporter (Table 5.8), the liquid fuels required for crop production, lubrication, and food processing and transportation are imported in significant amounts.

Australia is also dependent on overseas raw material for the production of fertilizers. Most of the herbicides, pesticides, and veterinary medicines used in Australian agriculture are currently imported from countries likely to be combatants in a major nuclear war. Although raw materials and alternative technologies could be developed to replace interrupted supplies of imports, there might be a significant time lag for complete replacement.

Decreased precipitation is the potential climatic stress of the chronic phase to which Australian agriculture is most vulnerable. Although increased precipitation is possible in the coastal areas during the chronic phase, substantial decreases could occur inland. The wide range of climatic possibilities and the possibility of a range of targeting intensities produces a wide range of potential agricultural responses during the chronic phase (Figure 5.6). If Australia were not targeted, and if the climatic changes were small, little direct impact on production would be expected. Unless production decreased below 25% of pre-war levels the surviving population could be easily supported. Thus, Australia appears to be among the least vulnerable of countries to post-war food shortages.

5.3.4 Brazil

Although Brazil spans both equatorial and Southern Hemisphere latitudes, and is not considered likely to be a nuclear target, severe impacts are possible following a nuclear war. Brazil is a diverse country climatically, ranging from tropical to sub-tropical and from very wet to drier steppe climates. Mean temperatures in the tropical regions of Brazil are typically 25°C in May–Aug. and are approximately 27°C in Nov.–Feb.; more temperate regions are approximately 10–20°C in May–Aug. and 20–25°C in Nov.–Feb. Much of Brazilian food agriculture is in temperate and sub-tropical regions. Mean temperatures below 10°C, and/or episodes of frost during the growing season, could be expected to completely eliminate agricultural production for one growing cycle. Thus, Brazil is quite vulnerable to even brief episodes of cold temperatures.

Brazil does not have sufficient stored food to support its full population for one year of no production, except under the most favorable circumstances (Table 5.9). The median or carryover cases indicate that human mortality resulting from insufficient food could occur, depending on the timing of the war. Less severe climatic impacts would cause less severe mortality in a food crisis, but a large fraction of current production is needed to support the current population. A large-scale food crisis and mortality would be an unprecedented catastrophe for Brazil, and would be expected to add to the societal and economic disruption caused by nuclear warfare.

In the chronic phase of a few years following a nuclear conflict, several factors indicate a substantial potential for agricultural impairment. Brazil imports large amounts of oil, coal, N-fertilizer, and grain (Table 5.10). Brazilian agriculture is subsidy dependent, with significant yield gains during the past 30 years (Figure 5.7). Although Brazil produces most of its electricity from hydroelectric plants, the other energy vulnerabilities could decrease production. Chronic phase temperature decreases of several °C and precipitation

TABLE 5.9

BRAZIL
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	433	233	17
Pulses	------	174	------
Beef	------	557	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	145 (119%)	78 (64%)	6 (5%)
Pulses	------	58 (48%)	------
Beef	------	187 (153%)	------

TABLE 5.10

BRAZIL 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	12,622	38,709	307
Hard Coal (1,000 MT)	6,400	4,406	69
Gasoline (1,000 MT)	8,841	(-1,149)	0
Diesel Fuel (1,000 MT)	16,268	(-825)	0
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	141,224	93	
Thermal	10,865	7	
Nuclear	--------	---	
Geothermal	--------	---	
TOTAL	152,089	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	349,400	319,100	91
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	330,000	1,000	0.3
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	2,000	74,670	3

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

decreases of 25 to 50% of normal could also cause problems, however there are possible methods of compensation. Brazil uses more than 10^6 ha for non-food and export crops. In the environment of a post-war economy, this land could be shifted to food production. In addition, the climatic diversity of Brazil indicates that at least some parts of the country would be suitable for agriculture, even if chronic climatic disturbances occur. Finding the appropriate crops and locations could, however, be a difficult operation for most farmers.

A range of possibilities for agricultural production in chronic phase Brazil is illustrated in Figure 5.8. Some agricultural impairment seems likely, even

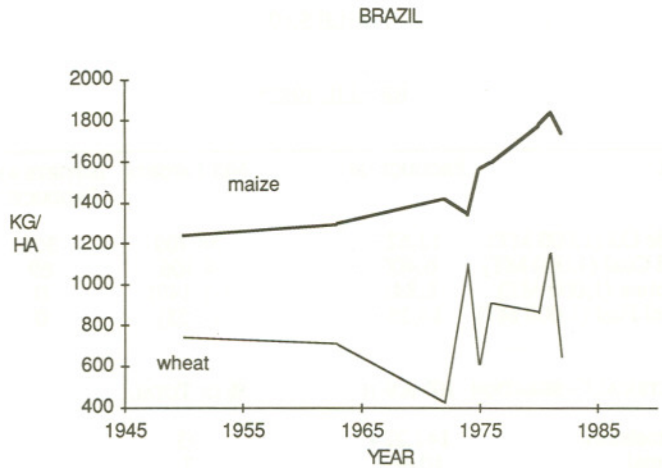

Figure 5.7 Maize and wheat yields in Brazil. (FAO production yearbooks)

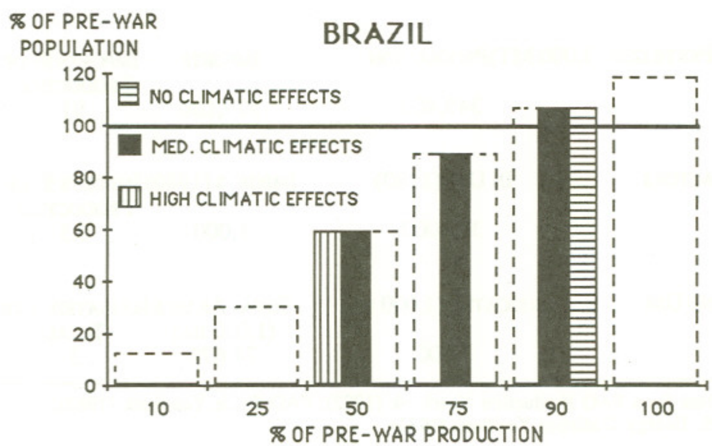

Figure 5.8 Chronic phase population support in Brazil

with no climatic impacts, due to the heavy import dependence of Brazil. Additional agricultural effects due to climatic stresses could reduce production below the levels necessary to support the current population.

5.3.5 Canada

Canadian agriculture would suffer severe consequences in a major nuclear war as a result of possible climatic disturbances and, perhaps, targeting. As

TABLE 5.11

CANADA
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	2,866	1,935	988
Pulses	------	808	------
Beef	------	347	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	95 (393%)	64 (265%)	33 (135%)
Pulses	------	27 (111%)	------
Beef	------	11 (48%)	------

a member of NATO, heavy destruction of industrial and urban areas associated with targets of military significance could greatly disrupt the complex system that supports current agriculture. In addition, Canadian agriculture is very sensitive to temperature declines, with the majority located between 44 and 55°N latitude. Simulation studies (Chapter 4) indicate that mean temperature decreases of a few degrees C could completely eliminate wheat

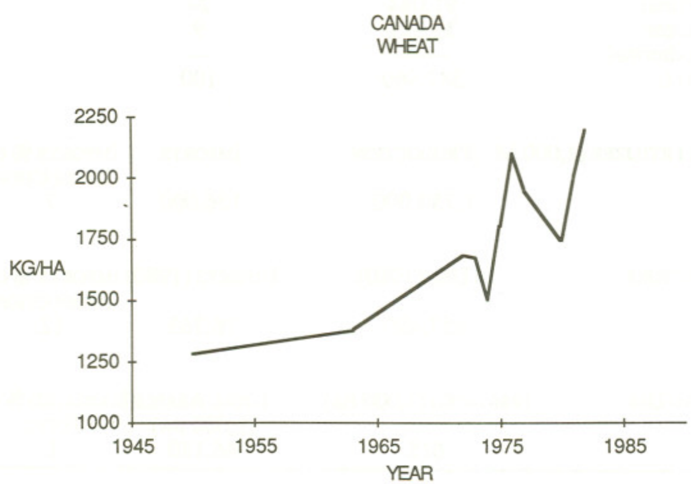

Figure 5.9 Wheat yield in Canada. (FAO production yearbooks)

production in Canada. Mean temperatures of approximately 15°C (May–Aug.) are common in the Canadian continental interior. Even relatively mild climatic disturbances could virtually eliminate Canadian agriculture for a single growing season, and in the worst cases, for a number of years.

However, the consequences to humans of the severe climatic stresses predicted for Canada are not necessarily as severe as in most other countries. The high levels of agricultural production relative to population size indicates that all survivors could be fed on stored food for an extended time period (Table 5.11). These calculations assume that the survivors would have

TABLE 5.12

CANADA 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	62,163	6,915	11
Hard Coal (1,000 MT)	22,379	(-331)	0
Gasoline (1,000 MT)	24,796	(-370)	0
Diesel Fuel (1,000 MT)	19,404	(-711)	0
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	261,055	67	
Thermal	91,084	24	
Nuclear	35,321	9	
Geothermal	-------	---	
TOTAL	387,460	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	1,750,000	126,000	7
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	657,400	76,763	12
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	615	46,180	1

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

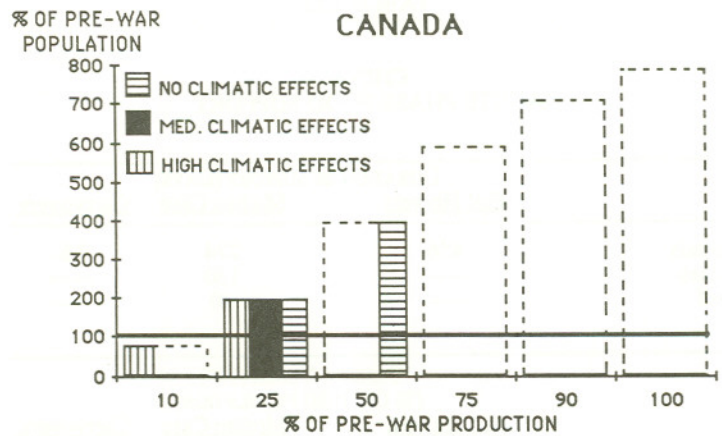

Figure 5.10 Chronic phase population support in Canada

the information and means to deliver food to the entire population. Given such assumptions, an acute phase food crisis need not occur in Canada.

The principal factors promoting recovery during the chronic phase are Canadian import independence and the potential strength of the agricultural system. Although Canada can produce the major energy sources and subsidies necessary for agriculture (Table 5.12), targeting of industry and refineries could seriously diminish this capacity for an extended time period. Yield decreases of 1,000 $kg \cdot ha^{-1}$ could occur with the implementation of a less subsidy-dependent agricultural system. Climatic stresses during the chronic phase could also reduce agricultural production. Only a small fraction of pre-war agricultural production would be necessary to support the full population of Canada (Figure 5.10), but the combined effects of these stresses could reduce production to insignificant levels.

5.3.6 China

The Chinese agricultural and food supply system is vulnerable to severe disruption and damage following a nuclear war, even if China were not a direct target. A high level of production must be maintained to feed 1,000 million people, an unlikely possibility given the possible post-nuclear war climatic disturbances. Because of its mid-latitude, continental location, China could experience mean temperatures 10 to 35°C below normal following a major nuclear war, with smaller reductions possible for an extended time period. Even temperature reductions at the mild end of this range would bring mean temperatures near the tolerance limits for rice in much of China, and would produce minimum temperatures that could eliminate rice production.

TABLE 5.13

CHINA
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	456	274	86
Pulses	------	130	------
Beef	------	40	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	933 (94%)	559 (56%)	176 (18%)
Pulses	------	265 (27%)	------
Beef	------	81 (8%)	------

Elimination of agricultural production would result in a food crisis in China under all but the most favorable circumstances (Table 5.13). If full annual production were in storage, adequate food for one year might be available, but median or carryover levels would support only a fraction of the current population. These calculations assume that both population and food stores would be destroyed as a direct effect of nuclear weapons, but

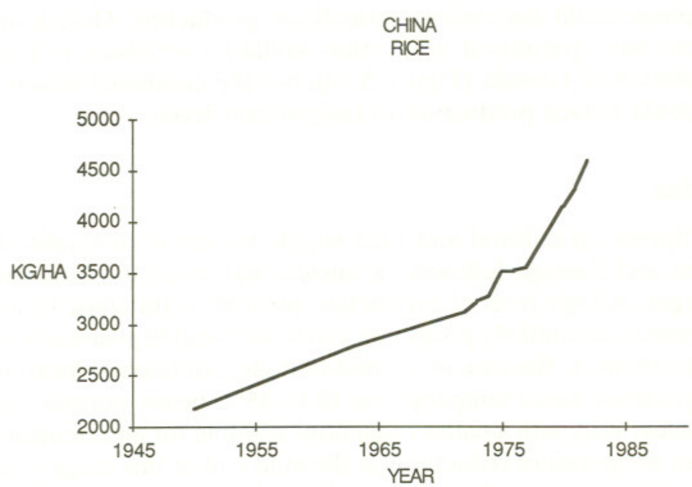

Figure 5.11 Rice yield in China. (FAO production yearbooks)

TABLE 5.14

CHINA 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	102,120	(-14,560)	0
Hard Coal (1,000 MT)	635,000	(-4254)	0
Gasoline (1,000 MT)	11,140	(-980)	0
Diesel Fuel (1,000 MT)	17,460	(-1,475)	0
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	74,400	23	
Thermal	253,280	77	
Nuclear	--------	---	
Geothermal	--------	---	
TOTAL	327,460	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	10,106,600	1,430,600	14
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	745,315	4,198	0.6
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	44,770	100,891	44

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

the results are not greatly improved if no stores are destroyed. In the worst cases, a majority of the Chinese population could suffer mortality related to food shortages. A disaster of this magnitude would multiply the societal disruption caused by a large-scale nuclear war.

Chronic-phase recovery would also present many problems for Chinese agriculture. The societal damages associated with targeting and/or an acute phase food crisis would make agricultural recovery much more difficult. Chinese agriculture is energy and subsidy intensive (see Chapter 4), and rice yields would be expected to decline significantly at low subsidy levels

(Figure 5.11). Although China currently produces most of the energy and subsidies necessary for modern agriculture (Table 5.14), the disruptions of communications, transportation, and industrial capacity associated with the acute phase could substantially eliminate the subsidies. An example of a potential vulnerability is irrigation. A large fraction of Chinese agricultural land is currently irrigated (Table 5.14), and requires significant amounts of labor and energy to maintain the system.

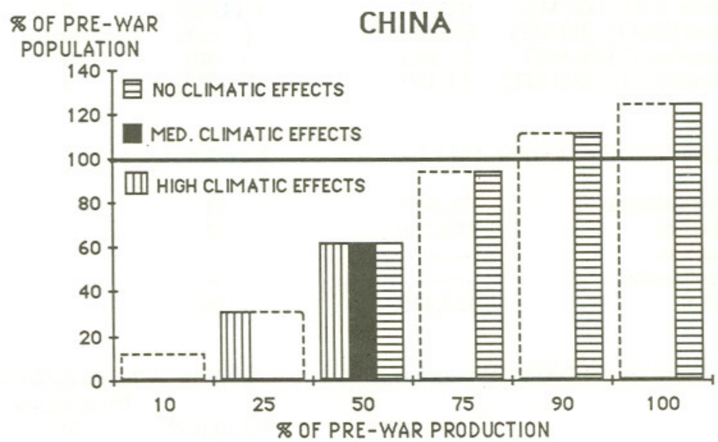

Figure 5.12 Chronic phase population support in China

A wide range of levels of Chinese agricultural production in the chronic phase seem possible (Figure 5.12). If China were not a target of nuclear weapons, and if climate effects were small or nonexistent, little reduction of agricultural production might occur. This is largely a reflection of the import independence of China. Direct nuclear attacks and climatic disturbances could reduce production levels substantially below those required to support the current population. China is particularly vulnerable to climate effects in the chronic phase, because of the importance of rice, a highly cold-sensitive plant.

5.3.7 Costa Rica

Agriculture and food distribution in Costa Rica, a tropical Northern Hemisphere country, could be seriously impaired by a major nuclear war. In the first several weeks following nuclear war, patchy occurrences of low temperatures could occur, although the Costa Rican climate is moderated greatly by the nearby marine influence. As a tropical country, mean temperatures vary little over the annual cycle, and generally range from 20 to 30°C at different locations. Extended periods 10 to 20°C below normal would cause large scale crop losses. Coastal areas might experience milder temperatures, and less severe impacts. Temperature reductions of several degrees could occur in the months following a nuclear war, with possible agricultural effects. Precipitation reductions, and shifts in timing, also might have potential agricultural consequences. Although precipitation increases are possible in coastal areas, decreases of up to 50% might occur in the interior regions as convective precipitation activity became suppressed. Precipitation decreases of up to 50% would not necessarily reduce crop production potential, particularly coupled with decreased temperatures (annual rainfalls of 2 to 3 meters are common). These changes might, however, require shifts of crop types and location by individual farmers, based on little or no climatic predictability.

Extended periods of crop failure and elimination of food imports would lead to food shortages in Costa Rica (Table 5.15). Even cereal stores equaling the full annual harvest would not be sufficient to feed the entire population for one year. In these circumstances, grain that is currently used to feed animals could be shifted to human consumption to replace imported grain. This assumption was made for the calculations in Table 5.15. Pulses might also be in short supply with no production, but cattle and other animals could be used to provide some of the missing calories. We have assumed that cow products are consumed at rates of 500 kcal$\cdot$person$^{-1}\cdot$day^{-1}. Higher consumption rates would reduce population support, and it is not clear whether

TABLE 5.15

COSTA RICA
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	224	135	23
Pulses	------	101	------
Beef	------	745	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	1.4 (61%)	0.8 (37%)	0.1 (6%)
Pulses	------	0.6 (28%)	------
Beef	------	4.5 (204%)	------

TABLE 5.16

COSTA RICA 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	0	450	---
Hard Coal (1,000 MT)	---	---	---
Gasoline (1,000 MT)	80	50	62
Diesel Fuel (1,000 MT)	140	200	143
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	2,430	97	
Thermal	70	3	
Nuclear	------	---	
Geothermal	------	---	
TOTAL	2,500	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	42,000	12,600	30
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	5,950	515	9
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	26	635	4

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

other food stores would be available to compensate for insufficient stored grain.

Costa Rican agriculture is vulnerable in the chronic phase following a nuclear war for a variety of reasons. If severe food shortages developed during the first year, recovery of production would be more difficult as a result of social disruption. As with grain, Costa Rica depends on imports for many items of agricultural significance (Table 5.16). Energy-intensive inputs are responsible for the recent large yield increases (Figure 5.13) in Costa Rican crops, leading to an unstable agricultural system (Schlichter et

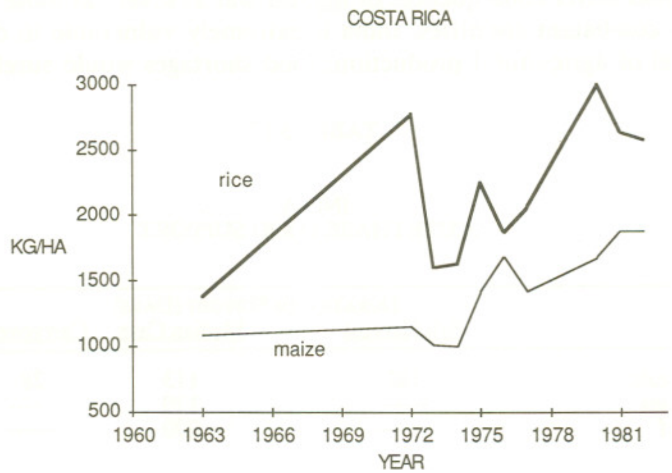

Figure 5.13 Rice and maize yields in Costa Rica (FAO production yearbooks)

al 1985). Ameliorating factors in the chronic phase include the large land area ($>10^6$ ha) used to produce export crops, and the large fraction of electricity produced in hydroelectric facilities. The wide range of climatic impacts, and the potential compensations for nuclear war stresses, lead to a wide range of potential productivities in the chronic post-war environment (Figure 5.14).

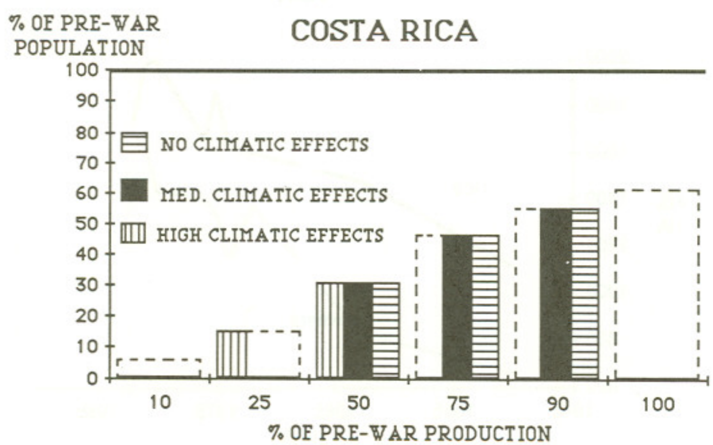

Figure 5.14 Chronic phase population support in Costa Rica

5.3.8 India

India could suffer consequences of nuclear war as severe as those faced by the major combatant countries. India is extremely vulnerable to decreases in the level of agricultural production; food shortages would surely follow

TABLE 5.17

INDIA
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	185	113	28
Pulses	------	170	------
Beef	------	200	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	347 (51%)	213 (31%)	53 (8%)
Pulses	------	319 (47%)	------
Beef	------	374 (55%)	------

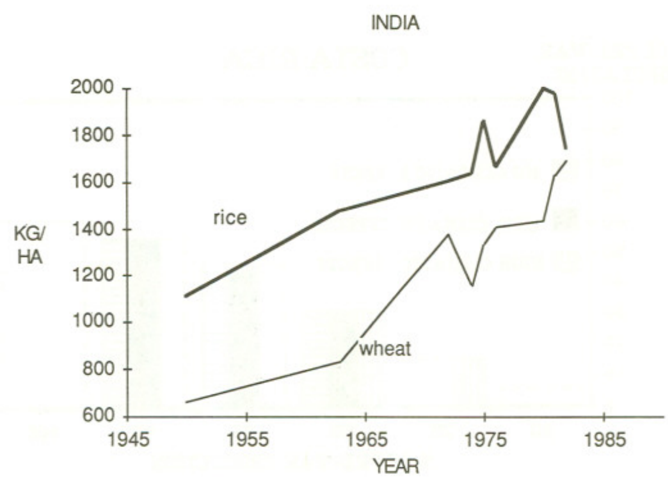

Figure 5.15 Rice and wheat yield in India. (FAO production yearbooks)

a post-war climatic disturbance covering the Northern Hemisphere. India spans a wide latitude range (approximately 10–35°N latitude) and has a wide range of climates. Annual rainfall ranges from less than 500 to more than 3,000 mm, and mean annual temperatures from about 15 to 30°C. Acute-phase reductions in mean temperature could range from relatively mild in some coastal regions to severe in dry inland regions with dense smoke cover. One of the critical considerations would be the timing of a war. Over longer periods, temperature decreases might be less, but the monsoon could be largely absent even for relatively small temperature decreases. Mean temperature reductions of 15°C or more would be expected

TABLE 5.18

INDIA 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	19,734	12,936	66
Hard Coal (1,000 MT)	128,320	1,160	1
Gasoline (1,000 MT)	1,750	0	0
Diesel Fuel (1,000 MT)	10,468	2,412	23
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	52,675	38	
Thermal	82,792	60	
Nuclear	3,210	2	
Geothermal	-------	---	
TOTAL	138,677	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	3,143,300	1,055,100	34
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	418,116	34	---
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	40,600	169,540	24

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

to eliminate agricultural production in India, as would large precipitation decreases associated with failure of the monsoons.

The consequences to India of diminished or eliminated production would be enormous. There is little capacity to feed the population on stored food (Table 5.17). Since there are two major grain harvests in India, even having a full harvest in storage would not support the population for one year. In the worst cases, most of the Indian population would suffer mortality related to food shortages. Although we have assumed India would not be a target of nuclear weapons for the purposes of these calculations, it is possible that India would be targeted, and that would increase the severity of acute phase impacts.

Indian agriculture could be affected by nuclear war for an extended period during the chronic phase. Severe acute-phase effects would slow agricultural recovery, even with no additional climatic impacts. Chronic-phase precipitation reductions could significantly reduce agricultural production. Rainfall in India tends to be highly seasonal, and alterations of rainfall patterns or failure or shifting of monsoons could produce extended difficulties. Chronic phase temperature decreases could produce problems for rice cropping in much of India. Indian agriculture relies on a number of energy inputs and subsidies (Hameed and Parimanam, 1983) to produce high grain yields (Figure 5.15). Without additional climatic disturbances, India might be able to compensate for losses of imported oil and fertilizers (Table 5.18), but with severe disruptions, and possible targeting, yields would be expected to decline.

India is currently independent of food imports, but there is little excess

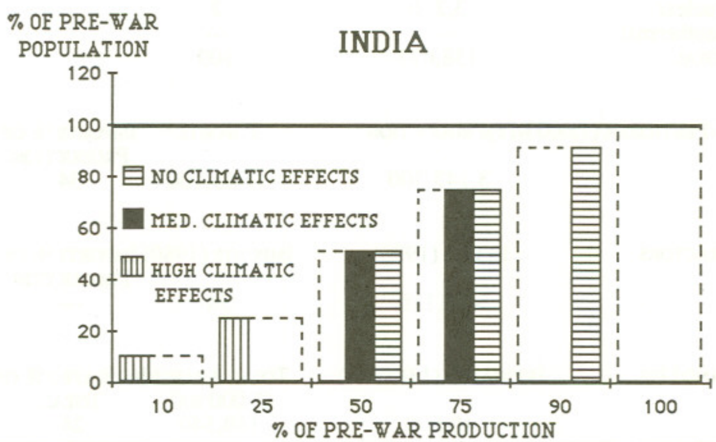

Figure 5.16 Chronic phase population support in India

agricultural production available (Figure 5.16). Given severe climatic scenarios, only a small fraction of the current population could be supported by the diminished agricultural system. Even with no nuclear weapon detonations in India, and no significant climatic stresses, some impact on agriculture could occur as a result of the massive disruption of the international economy and trade expected after a major nuclear war.

5.3.9 Indonesia

The effects of nuclear war on Indonesia are difficult to predict, and depend to a large extent on the severity of climate stresses that would be experienced in equatorial islands. Temperature reductions in the Indonesian tropical lowlands could be moderated by the surrounding ocean. Temperature decreases of a few degrees C would probably not seriously impair agriculture in regions with mean temperatures of 25 to 30°C. Temperature decreases in the range of 5 to 15°C could have a major impact on Indonesian agriculture.

TABLE 5.19

INDONESIA
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	67	67	37
Pulses	------	227	------
Beef	------	32	------

	Person-Years(10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	27 (18%)	27 (18%)	15 (10%)
Pulses	------	92 (62%)	------
Beef	------	13 (9%)	------

Food storage could be a serious problem in the chronic phase if production were eliminated for more than a few months (Table 5.19). Temperature variations are small in the tropical climate of Indonesia, and agricultural production is normally possible throughout the year. The calculations in Table 5.19 are based on the assumption that 1/12 of annual production would be available in storage at any time. The median and full harvest cases

TABLE 5.20

INDONESIA 1982[a]

Fuel	Production	Net Imports	Imports as % Production
Crude Oil (1,000 MT)	65,853	(-51,887)	0
Hard Coal (1,000 MT)	481	(-208)	0
Gasoline (1,000 MT)	1,971	1,394	71
Diesel Fuel (1,000 MT)	4,855	275	6
Electrical Generation	10^6 KWh	% of Total	
Hydroelectric	1,560	21	
Thermal	5,805	79	
Nuclear	------	---	
Geothermal	------	---	
Total	7,365	100	
N-Fertilizer (1,000 MT)	Production	Imports	Imports % of Production
	966,443	183,620	19
Tractors	In Use (1980)	Imports (1980)	Imports % of Production
	13,000	5,149	40
Land Use	Irrigated (1,000 ha)	Total Arable (1,000 ha)	Irrigated % of Total
	5,450	19,600	28

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

are both based on this level of food storage. If no other food were available, a massive food crisis would result from the severe climate scenarios.

The significance of potential chronic phase agricultural impacts also depends largely on the severity of climatic impacts experienced. Indonesia is a major energy exporter (Table 5.20), and although there are significant imports of refined energy products and machinery, relatively small impacts are expected independent of climatic stress. High-yield, energy-intensive rice (Figure 5.17) is the major cereal crop in Indonesia. In the severe scenarios for chronic phase temperature and precipitation reductions, annual rice

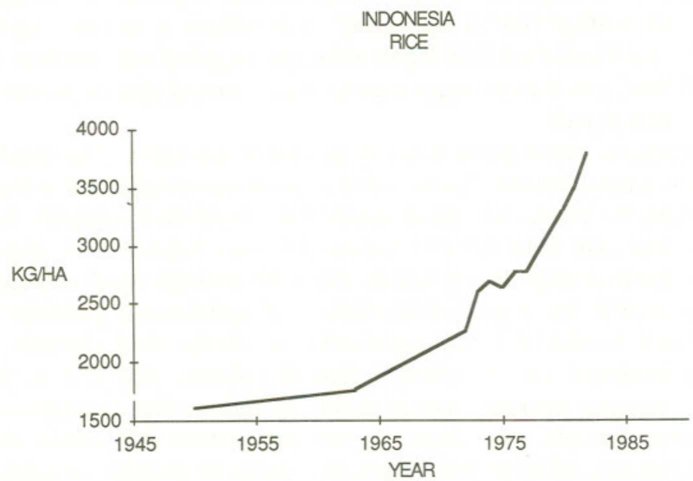

Figure 5.17 Rice yield in Indonesia. (FAO production yearbooks)

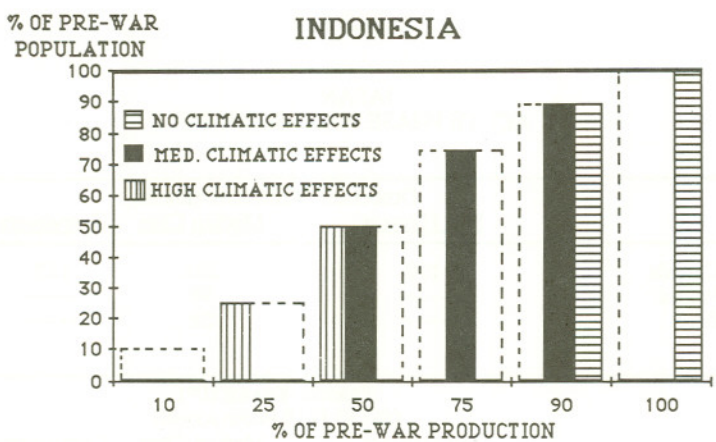

Figure 5.18 Chronic phase population support in Indonesia

production levels might not be substantially reduced, but large changes in precipitation levels or patterns could cause serious problems.

5.3.10 Japan

Japan would be likely to suffer devastating impacts following a major nuclear war, with vulnerabilities in all of the categories we have analyzed.

Japan could be a target of nuclear weapons and experience damage to the industry and transportation necessary to maintain a modern agricultural system. We have assumed that Japan would be targeted with nuclear weapons in a major war, but the consequences to Japan would also be severe if there were no direct attack.

Japan imports more grain than it produces annually. The median case food support calculations (Table 5.21) include carryovers and a fraction of annual imports. Therefore, food stores for population support is greater in the median case than for full harvest without imports. For none of the calculated food storage levels would there be enough food to support the entire population for a year. Elimination of agricultural production for a year or more would be likely from even relatively mild climatic stresses. Historical evidence and simulation studies indicate that a 3 to 5 degree mean temperature decrease would seriously reduce rice production, and a larger decrease would make Japanese rice production impossible. An acute-phase food crisis and large-scale mortality would be possible in such circumstances.

TABLE 5.21

JAPAN
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	190	201	153
Pulses	------	99	------
Beef	------	28	------

	Person-Years(10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	30 (26%)	32 (28%)	24 (21%)
Pulses	------	16 (14%)	------
Beef	------	5 (4%)	------

Chronic-phase impacts on Japan following a nuclear war could interfere with agricultural recovery. Temperature decreases could continue to inhibit Japanese agricultural production for a year or more following a war, since it is downwind of a large continental area that might have temperatures well below normal. In the worst scenarios, rice production would be impossi-

TABLE 5.22

JAPAN 1982[a]

Fuel	Production	Net Imports	Imports as % Production
Crude Oil (1,000 MT)	397	177,455	44,699
Hard Coal (1,000 MT)	17,606	79,066	499
Gasoline (1,000 MT)	26,348	0	0
Diesel Fuel (1,000 MT)	34,979	1,486	4
Electrical Generation	**10^6 KWh**	**% of Total**	
Hydroelectric	84,039	14	
Thermal	393,405	68	
Nuclear	102,430	18	
Geothermal	1,273	0.2	
Total	581,147	100	
N-Fertilizer (1,000 MT)	**Production**	**Imports**	**Imports % of Production**
	1,032,000	48,000	5
Tractors	**In Use (1980)**	**Imports (1980)**	**Imports % of Production**
	1,471,400	5,348	0.4
Land Use	**Irrigated (1,000 ha)**	**Total Arable (1,000 ha)**	**Irrigated % of Total**
	3,230	4,829	67

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

ble indefinitely. Even with no climatic impacts, the heavy Japanese reliance on imported energy (Table 5.22) would seriously impair the current energy-intensive system. With reduced subsidies, yield declines of up to 1,000–2,000 $kg \cdot ha^{-1}$ could occur (Figure 5.19). Chronic phase impacts are summarized in Figure 5.20. Because of Japan's import dependence, even 100% of current production could not sustain the current population at steady state. The additional impacts of nuclear detonations, climatic stress, and energy shortages could each significantly reduce Japanese agriculture. The combined impacts of all of these stresses would be devastating.

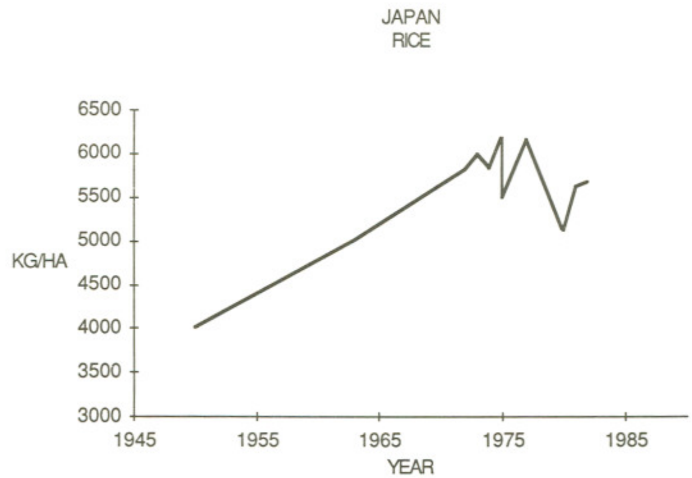

Figure 5.19 Rice yield in Japan. (FAO production yearbooks)

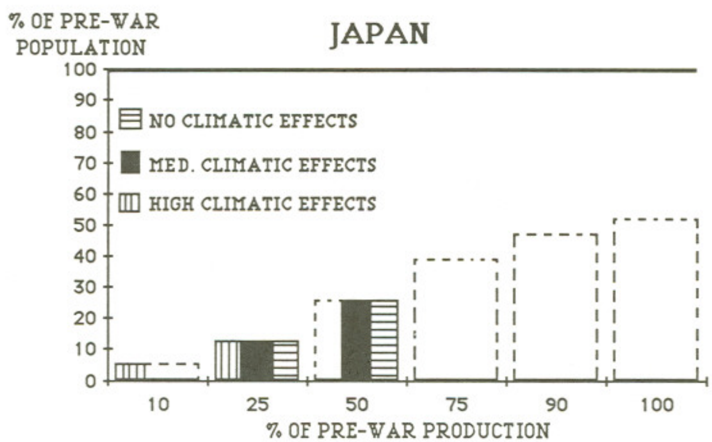

Figure 5.20 Chronic phase population support in Japan

5.3.11 Kenya

Although Kenya is unlikely to be a direct target of nuclear weapons, significant indirect effects could be experienced following a major nuclear conflict. Climatic stresses in the acute phase could reduce agricultural productivity, particularly in the uplands. Large precipitation decreases are possible in the acute phase and might continue into the chronic phase if the monsoons were altered. Transient freezing could also occur in the initial weeks under dense smoke clouds. A nuclear war occurring in the Northern Hemisphere spring or summer would have greater potential for agricultural damage, but yield reductions could also occur after an autumn or winter war.

Kenya would be vulnerable to an acute phase food crisis if cereal production were eliminated for a year or more (Table 5.23). The median and carryover cases indicate that only a fraction of the Kenyan population could be supported for one year on stored food alone. Kenya's cereal imports were 17% of domestic production (1980), and even if the full annual production were in storage, there might be insufficient food for the entire population. Three-quarters of Kenya's population is classified as agricultural (Table 5.1), and its farmers make extensive use of household gardens, an ameliorating factor in a food crisis when compared to more urbanized countries in the same circumstances. The duration and severity of climatic stresses experienced are the principal variables controlling the probability of a food crisis in Kenya.

In the chronic phase, a number of factors could extend nuclear war im-

TABLE 5.23

KENYA
ACUTE PHASE FOOD SUPPORT

	DURATION OF SUPPORT (DAYS)		
	Full Harvest	Median Case	Carryovers
Cereals	251	141	25
Pulses	------	172	------
Beef	------	500	------

	PERSON-YEARS (10^6) (% OF 1980 POPULATION)		
	Full Harvest	Median Case	Carryovers
Cereals	11 (69%)	6 (39%)	1 (7%)
Pulses	------	8 (47%)	------
Beef	------	23 (137%)	------

pacts for several years. Climatic alterations could continue in this period and influence agriculture. Mean temperature decreases of several degrees C and precipitation decreases could reduce yields, increase the time necessary for crop maturity, and require shifts in crop systems and locations. Even with no climatic alterations, a major nuclear war would produce problems in Kenya as a result of disruptions of the international economy and trade. Kenya imports all of it's crude oil, coal, and N-fertilizer, as well as significant amounts of machinery (Table 5.24). The elimination or reduction of these imports could be expected to reduce yields by as much as 1,000 kg$\cdot$ha^{-1} (Figure 5.21). If climatic stresses were added to import deficiencies of food, energy, and machinery, agricultural production in Kenya could fall to levels much smaller than current (Figure 5.22).

TABLE 5.24

KENYA 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	0	2,426	---
Hard Coal (1,000 MT)	0	32	---
Gasoline (1,000 MT)	322	-69	0
Diesel Fuel (1,000 MT)	464	-101	0
ELECTRICAL GENERATION	**10^6 KWH**	**% OF TOTAL**	
Hydroelectric	1,397	77	
Thermal	311	17	
Nuclear	------	---	
Geothermal	96	5	
TOTAL	1,804	100	
N-FERTILIZER (1,000 MT)	**PRODUCTION**	**IMPORTS**	**IMPORTS % OF PRODUCTION**
	0	33,900	---
TRACTORS	**IN USE (1980)**	**IMPORTS (1980)**	**IMPORTS % OF PRODUCTION**
	6,546	5,752	88
LAND USE	**IRRIGATED (1,000 HA)**	**TOTAL ARABLE (1,000 HA)**	**IRRIGATED % OF TOTAL**
	50	2,388	2

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

Figure 5.21 Maize yield in Kenya. (FAO production yearbooks)

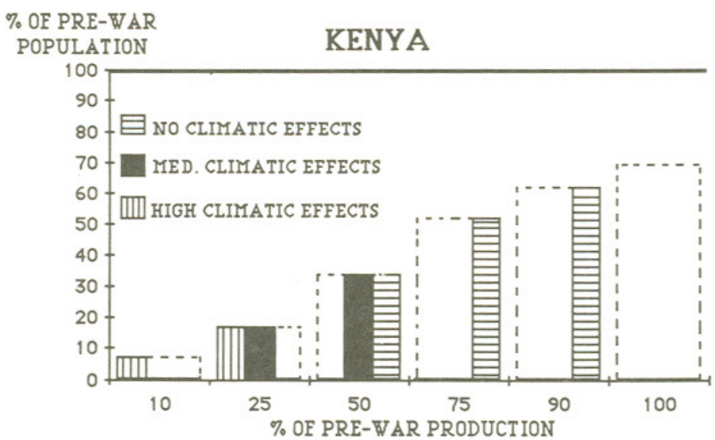

Figure 5.22 Chronic phase population support in Kenya

5.3.12 Nigeria

Nigeria is potentially vulnerable to the climatic disturbances that might follow a nuclear war. These climatic stresses would affect the coastal mangrove and rainforest region differently from the savannahs and arid regions in the north. In the severe case, prolonged periods of temperatures depressed by 10 to 20°C could be experienced throughout the country, seriously affecting agricultural production. Mean temperature decreases of less than 5°C might improve yields, but any precipitation decreases during the first post-war year could be very serious and might extend for years if the monsoon were affected. In the event of a prolonged period of no agricultural production or imports, the food stores could not support the entire population for one year (Table 5.25).

TABLE 5.25

NIGERIA
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	241	137	25
Pulses	------	288	------
Beef	------	119	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	51 (66%)	29 (37%)	5 (7%)
Pulses	------	61 (79%)	------
Beef	------	25 (33%)	------

Climatic stress, particularly precipitation decreases, might be the most serious concern for the chronic phase. Prolonged periods of rainfall at levels 25 to 50% of normal could lead to significant declines in agricultural production. Nigeria is a major energy exporter (Table 5.26) and should be able to maintain some agricultural subsidies at current rates. Imports of N-fertilizer and machinery are significant, but crop yields (Figure 5.23) are currently low. Elimination of imports could reduce the amount of marginal land used for agriculture. With no climatic effects, current levels of agricultural production could probably be maintained (Figure 5.24).

TABLE 5.26

NIGERIA 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	63,800	(-56,900)	0
Hard Coal (1,000 MT)	210	0	0
Gasoline (1,000 MT)	2,600	20	1
Diesel Fuel (1,000 MT)	1,900	-20	0
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	4,000	53	
Thermal	3,500	47	
Nuclear	------	---	
Geothermal	------	---	
TOTAL	7,500	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	0	96,700	---
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	8,600	2,950	34
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	30	30,435	0.1

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

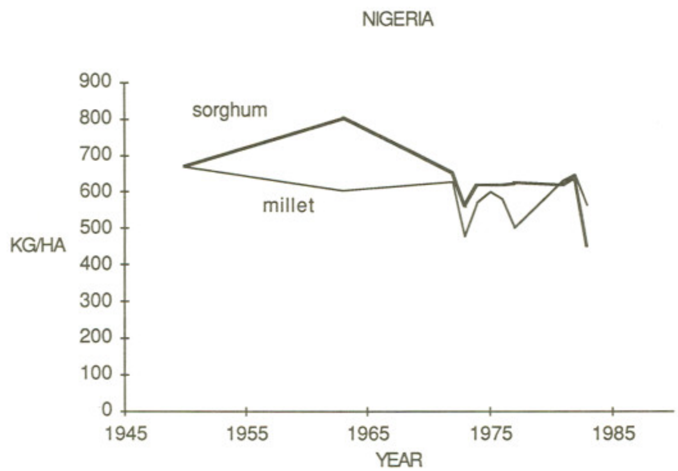

Figure 5.23 Millet and sorghum yields in Nigeria. (FAO production yearbooks)

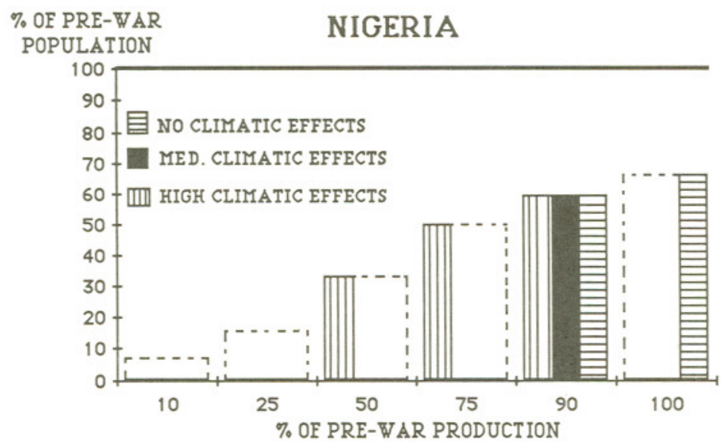

Figure 5.24 Chronic phase population support in Nigeria

5.3.13 Philippines

The Philippine islands cover a wide latitude range within the Northern Hemisphere tropical zone. Coastal environments in the acute phase could expect mean temperature decreases of about 5 degrees or less. Temperature

TABLE 5.27

PHILIPPINES
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	179	119	36
Pulses	------	195	------
Beef	------	29	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	24 (49%)	16 (33%)	5 (10%)
Pulses	------	26 (53%)	------
Beef	------	4 (8%)	------

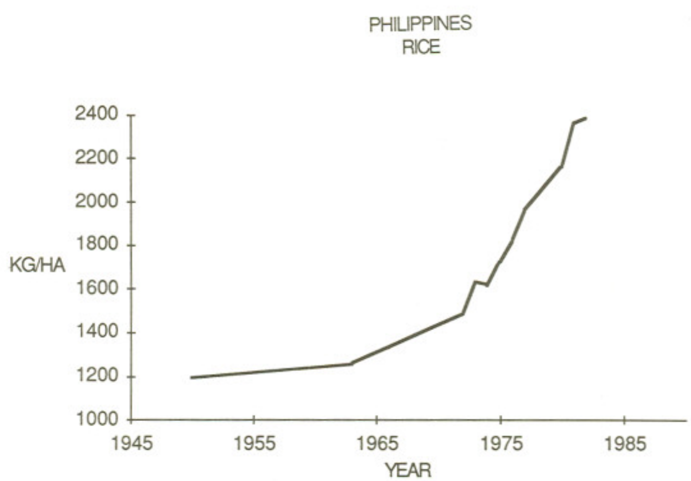

Figure 5.25 Rice yield in the Philippines. (FAO production yearbooks)

changes of this magnitude would not eliminate agriculture because mean temperatures between 25 and 30°C are typical in the Philippine lowlands. Short-term episodes of somewhat larger temperature decreases might occur in the acute phase as the result of the passage of dense smoke clouds or from colder air masses moving off of the Asian continent. Rice production in the Philippines would be very vulnerable to such episodes of chilling temperatures.

The Philippines are vulnerable to a food shortage crisis with no agricultural production for an extended time period (Table 5.27), but the current climatic analysis (Volume 1) indicates that such conditions are not likely. The chronic-phase nuclear war impacts on the Philippines could be diverse.

TABLE 5.28

PHILIPPINES 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	463	9,636	2,081
Hard Coal (1,000 MT)	558	4	1
Gasoline (1,000 MT)	1,231	(-20)	0
Diesel Fuel (1,000 MT)	2,325	1,450	62
ELECTRICAL GENERATION	10^6KWH	% OF TOTAL	
Hydroelectric	3,773	19	
Thermal	12,093	62	
Nuclear	-------	---	
Geothermal	3,540	18	
TOTAL	19,406	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	40,200	187,000	465
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	17,000	1,703	10
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	1,370	11,800	12

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

Port facilities and U.S. military bases could be targets of nuclear weapons, imports of energy and N-fertilizer could be reduced, and climatic changes could affect the rice production system.

Philippine agriculture is high-yield (Figure 5.25) and energy intensive. High levels of oil and N-fertilizer imports relative to domestic production (Table 5.28) indicates that Philippine agriculture may be vulnerable to indirect reductions as a result of import elimination. Rice is the principal cereal crop in the Philippines, and is very sensitive to reduced temperatures (Chapter 4). Mean temperatures in the Philippines are generally between 25 and 30°C, and small temperature decreases in the chronic phase might not additionally reduce agricultural production (Figure 5.26). Decreased precipitation, or alterations of timing and duration of rainy periods could affect Philippine agricultural production.

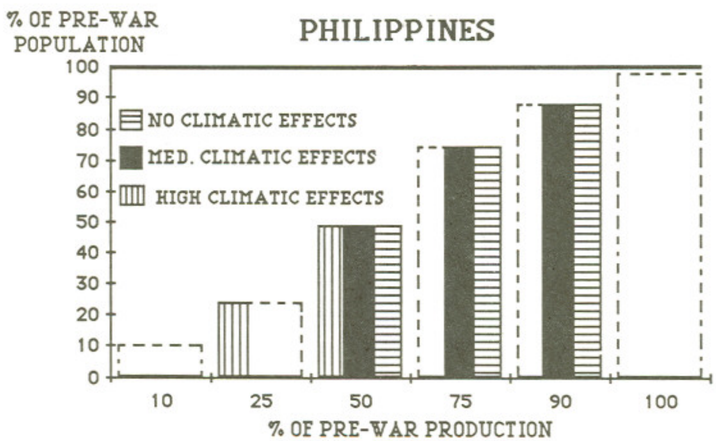

Figure 5.26 Chronic phase population support in the Philippines

5.3.14 United Kingdom

The major impacts of nuclear war on the United Kingdom would be associated with the effects of nuclear detonations. Openshaw et al. (1983) estimated that 20 to 90% of the U.K. population would be casualties in attacks ranging from 40 to 350 megatons of total yield. In addition to massive human casualties, Openshaw et al. described the destruction of large parts of the energy, fuel, and water supply systems, as well as much of industry and transportation.

A large-scale nuclear attack on the U.K. would also cause serious problems for food supply and agriculture. Destruction of food shops and warehouses in urban areas, and the electrical system necessary to maintain frozen food stores, could exacerbate the difficulties of providing food to survivors. If 75% of the population and food supplies were destroyed in a nuclear attack, there might be an adequate amount of food for the survivors (Table 5.29), but food distribution problems would increase difficulties. Mean temperature decreases of 5 to 10°C would be severe enough to eliminate additional agricultural production in the first year following the war.

TABLE 5.29

UNITED KINGDOM
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	600	382	136
Pulses	------	352	------
Beef	------	161	------
	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	23 (41%)	15 (26%)	5 (9%)
Pulses	------	14 (24%)	------
Beef	------	6 (11%)	------

Many of the problems of the acute phase would continue to impair the recovery of U.K. agricultural production in the chronic phase. Climatic stresses of decreased temperature and precipitation would decrease potential yields, as well as the effects of destruction of the industrial system supporting modern agriculture in the United Kingdom. Residual radioactivity from local fallout could contaminate a substantial fraction of the arable land. Although the United Kingdom is a net energy exporter (Table 5.30), destruction of refineries, transportation facilities, and electrical generators would make it difficult to maintain the high yields typical of pre-war agriculture (Figure 5.27). The combined effects of these stresses and destruction would be to reduce the support capacity of U.K. agriculture to a small fraction of pre-war levels (Figure 5.28).

TABLE 5.30

UNITED KINGDOM 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	103,647	(-26,465)	0
Hard Coal (1,000 MT)	124,711	(-3,448)	0
Gasoline (1,000 MT)	19,135	(-1,302)	0
Diesel Fuel (1,000 MT)	20,598	(-2,918)	0
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	5,637	2	
Thermal	222,553	82	
Nuclear	43,972	16	
Geothermal	---------	---	
TOTAL	272,162	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	1,270,000	222,000	17
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	512,494	12,924	3
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	152	6,978	2

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

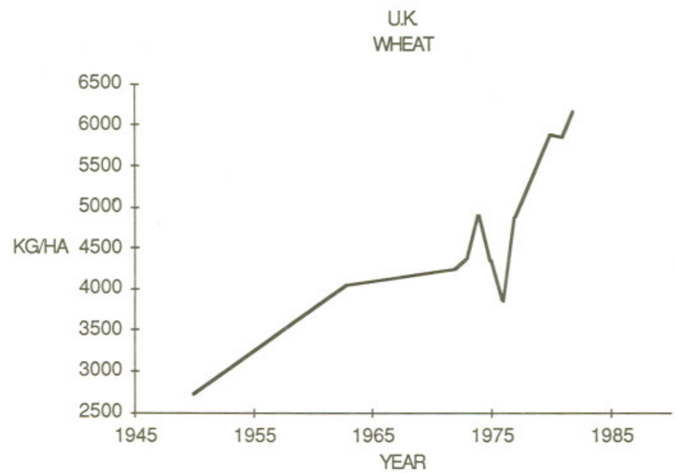

Figure 5.27 Wheat yield in the United Kingdom. (FAO production yearbooks)

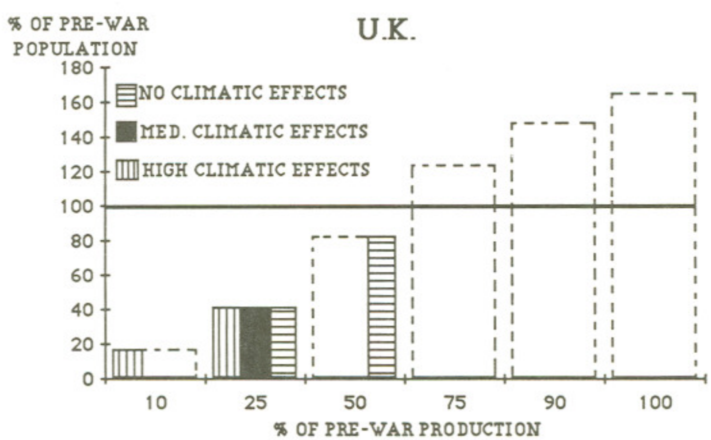

Figure 5.28 Chronic phase population support in the United Kingdom

5.3.15 U.S.A.

The effects of blast, fire, and local fallout "hotspots" would seriously impair the agricultural system of the United States following a major nuclear war. Human casualties of between 50 and 150 million, as well as destruction of most of the industrial system supporting agriculture, would decrease production levels (Harwell, 1984). The subsequent climatic disturbances could essentially eliminate agricultural production in the U.S.A. for at least one year. Mean temperature decreases up to 20 to 40°C and short-term precipitation decreases of up to 100% are possible during the first few weeks. Climatic stresses of half this magnitude could essentially eliminate an entire growing season of production. These impacts would not be confined to the production of grains. Only a small fraction of the current levels of production of animal products and other crops would occur in the first year following a nuclear war (Harwell, 1984).

TABLE 5.31

U.S.
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	2,000	1,290	579
Pulses	------	487	------
Beef	------	329	------

	Person-Years (10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	312 (137%)	201 (88%)	90 (40%)
Pulses	------	76 (33%)	------
Beef	------	51 (23%)	------

The U.S.A. is a major food exporter, with large amounts of stored grain. After an extensive nuclear war it is unlikely that the ability to continue food exports from the remaining stores would exist. This could propagate food shortages to non-combatant countries. As a massive food producer, there are potentially enough food stores to feed the entire surviving United States population for a period of several years (Table 5.31). Serious difficulties in the remaining food distribution and transportation systems could reduce effective food supplies significantly for urban area survivors.

The societal disruptions of a major nuclear attack on the United States would probably continue to impair agricultural recovery for a number of years. In addition, climatic stresses could be significant for up to a few years. Chronic-phase mean temperatures 5 to 10 degrees below normal are possible the first year, as well as precipitation decreases of up to 50% below normal. In the severe chronic climatic cases, agricultural production in the United States would remain difficult for several years. Even milder climatic changes could cause additional disruption of the production system. Mean temperature shifts of only a few degrees could alter the locations where specific crops could be grown. Planting times and frost probabilities could shift enough to make previous experience useless.

The current agricultural system of the United States is energy intensive and high yield (Figure 5.29). Yield decreases of 1,000 to 5,000 $kg \cdot ha^{-1}$ could

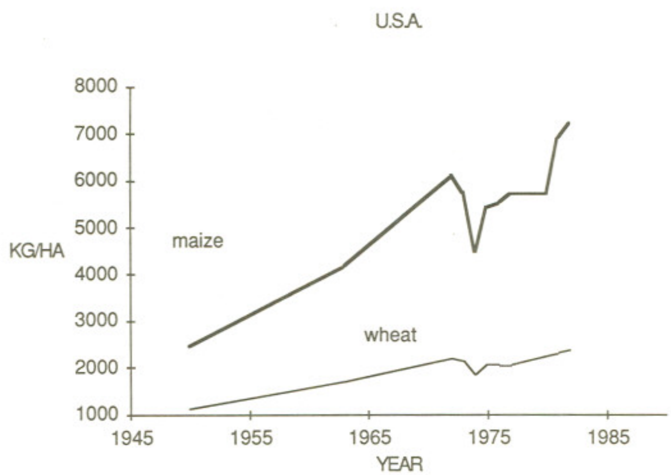

Figure 5.29 Wheat and maize yields in the U.S.A. (FAO production yearbooks)

occur if energy subsidies were cut off. Although the United States has the capability to supply the energy required for modern agriculture (Table 5.32), this capability would be reduced after a major nuclear war (Harwell 1984). Even a relatively small fraction of current agricultural production would support the pre-war population (Figure 5.30), but production decreases in the chronic phase might be reduced below this level.

TABLE 5.32

U.S. 1982[a]

Fuel	Production	Net Imports	Imports as % Production
Crude Oil (1,000 MT)	425,591	161,529	38
Hard Coal (1,000 MT)	707,226	(-95,692)	0
Gasoline (1,000 MT)	272,153	7,602	3
Diesel Fuel (1,000 MT)	131,579	956	1
Electrical Generation	10^6 KWh	% of Total	
Hydroelectric	310,788	13	
Thermal	1,705,807	74	
Nuclear	282,773	12	
Geothermal	4,843	1	
Total	2,304,211	100	
N-Fertilizer (1,000 MT)	Production	Imports	Imports % of Production
	10,513,000	2,296,000	22
Tractors	In Use (1980)	Imports (1980)	Imports % of Production
	4,740,000	93,035	2
Land Use	Irrigated (1,000 ha)	Total Arable (1,000 ha)	Irrigated % of Total
	20,582	190,624	11

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

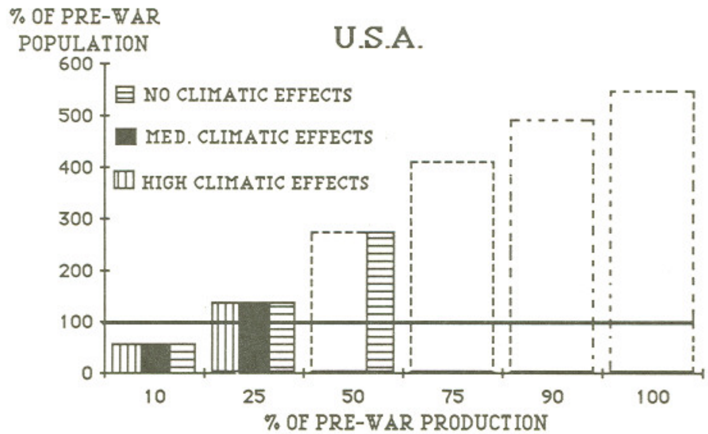

Figure 5.30 Chronic phase population support in the U.S.A.

5.3.16 U.S.S.R.

Agriculture in the Soviet Union is vulnerable to major disruption and reduction following a large-scale nuclear war. Climatic stresses and the effects of nuclear weapon detonations are the principal dangers to Soviet agricul-

TABLE 5.33

U.S.S.R.
ACUTE PHASE FOOD SUPPORT

	Duration of Support (Days)		
	Full Harvest	Median Case	Carryovers
Cereals	1,113	622	98
Pulses	------	1,179	------
Beef	------	292	------

	Person-Years(10^6) (% of 1980 Population)		
	Full Harvest	Median Case	Carryovers
Cereals	202 (76%)	113 (43%)	18 (7%)
Pulses	------	214 (81%)	------
Beef	------	53 (20%)	------

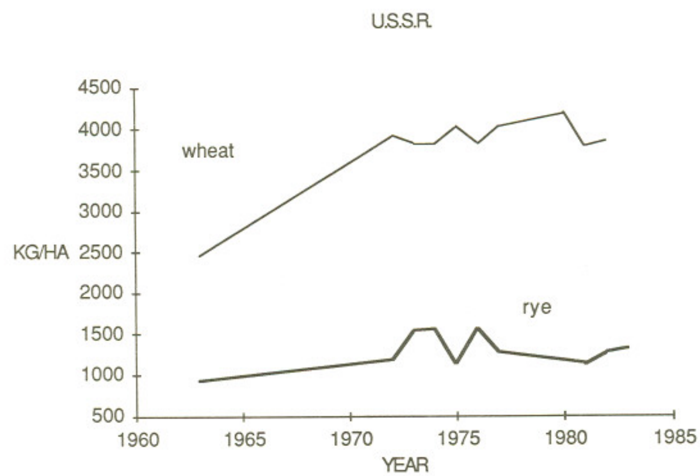

Figure 5.31 Wheat and rye yields in the U.S.S.R. (FAO production yearbooks)

ture. The destruction of a large fraction of the industrial and urban areas associated with military targets would have the additional effect of disrupting the complex system that supports current agriculture.

The Soviet Union is a large, diverse country containing every type of climate, except tropical. Much of the agricultural production in the Soviet Union is associated with mean annual temperatures below 15°C. These areas would be especially vulnerable to the effects of climatic disturbances. As in Canada, Soviet agriculture could be completely eliminated by temperature and precipitation decreases in the first post-war year. The Soviet Union has a strong agricultural system, and stored food could probably support the survivors if distribution systems were intact (Table 5.33). If the war occurred during annual minimum food storage levels (the carryover case), however, food shortages could be a problem even with an intact distribution system.

In the chronic-phase, Soviet agriculture would continue to be vulnerable to climatic stresses and to the effects of massive destruction caused by nuclear weapons. Chronic-phase temperature decreases of even several degrees, coupled with precipitation decreases up to 50% of normal, might be possible for an extended time period. These, or smaller magnitude stresses, could significantly reduce agricultural production. Even with no climatic stresses, agricultural recovery in the Soviet Union would be impaired by the disruption of the industrial and transportation system necessary for modern agriculture. Wheat yields could decline by one-third or more if energy subsidies were eliminated (Figure 5.31). Although the Soviet Union is an

TABLE 5.34

U.S.S.R. 1982[a]

FUEL	PRODUCTION	NET IMPORTS	IMPORTS AS % PRODUCTION
Crude Oil (1,000 MT)	612,600	(-120,000)	0
Hard Coal (1,000 MT)	488,022	(-11,131)	0
Gasoline (1,000 MT)	77,000	(-7,500)	0
Diesel Fuel (1,000 MT)	121,000	(-22,400)	0
ELECTRICAL GENERATION	10^6 KWH	% OF TOTAL	
Hydroelectric	175,277	13	
Thermal	1,111,823	81	
Nuclear	80,000	6	
Geothermal	----------	---	
TOTAL	1,367,100	100	
N-FERTILIZER (1,000 MT)	PRODUCTION	IMPORTS	IMPORTS % OF PRODUCTION
	10,581,000	32,700	0.3
TRACTORS	IN USE (1980)	IMPORTS (1980)	IMPORTS % OF PRODUCTION
	2,562,000	6,000	0.2
LAND USE	IRRIGATED (1,000 HA)	TOTAL ARABLE (1,000 HA)	IRRIGATED % OF TOTAL
	18,608	232,266	8

[a] Data from FAO Production Yearbook (1982); FAO Trade Yearbook (1982); U.N. Energy Statistics Yearbook (1983).

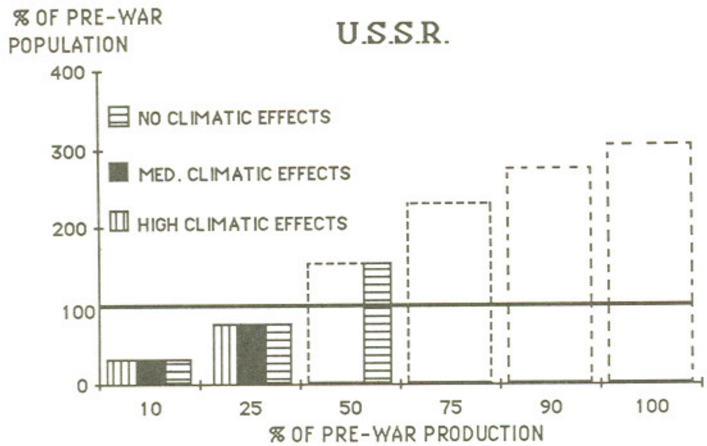

Figure 5.32 Chronic phase population support in the U.S.S.R.

energy exporter (Table 5.34), it would not likely be capable of using and delivering these resources for agricultural production for an extended period. With no climatic stresses, the steady-state carrying capacity of Soviet agriculture could be large enough to support the entire pre-war population (Figure 5.32), but prolonged climatic stresses could reduce production to a small fraction of current levels.

5.4 SENSITIVITY ANALYSES

The calculations of acute-phase food support in each country depend on a number of assumptions. Many of our assumptions were intended to provide a *maximum* estimate of the number of people that could live one year on stored food. Several of these assumptions have been tested with sensitivity analyses.

We have assumed that no animals are fed on stored grain. Animals would be available for direct consumption, and if adequate food were otherwise available, herds could persist at reduced levels through grazing. Consumption of grain directly is more energy efficient, and larger human populations could be maintained on a shorter food chain. We have also assumed a dietary consumption rate of 1,500 kcal$\cdot$person$^{-1}\cdot$day^{-1} for cereals. Cereals are currently the largest dietary component in most of the countries considered (Table 5.3). We have assumed this level of cereal consumption because it is not clear that other food stores would be available to provide the minimum requirement of approximately 2,000 kcal$\cdot$person$^{-1}\cdot$day^{-1} (based on FAO calculations).

TABLE 5.35

FOOD DISTRIBUTION: SENSITIVITY
CARRYOVERS

Usage Rate ($kcal \cdot person^{-1} \cdot day^{-1}$)	Person-Years (10^6)	Distribution Assumption
1,233	82	optimal
1,500	67	optimal
1,233	54	2% of population uses or stores 3,000 $kcal\ person^{-1}\ day^{-1}$
1,233	56	full population supported 14 days, then optimal.

The importance of dietary consumption rates can be tested through sensitivity analysis. Using the India data as an example (Table 5.35), it is clear that a dietary consumption rate of 1,233 $kcal \cdot person^{-1} \cdot day^{-1}$ (based on FAO food balance sheet averages) would still result in only a small fraction of the current population supported by carryovers. We have also compared consumption rates of 1,000 and 1,500 $kcal \cdot person^{-1} \cdot day^{-1}$ for both median and carryover cases (see section 5.5) on a global basis. These calculations indicate that the same pattern of vulnerability to food shortages demonstrated by the analysis of 15 countries holds true even at lower consumption rates. If only 1,000 $kcal \cdot person^{-1} \cdot day^{-1}$ were available, other food stores would have to be found to provide long-term population support. Proper nutrition requires more than the minimum energy requirements we have assumed. Fruit and vegetable production would be vulnerable to the climatic effects of nuclear war, and the survivors could be seriously malnourished in terms of Vitamins A, B_{12}, C, and riboflavin (Harwell, 1984).

One of the most critical assumptions of the food calculations is that of optimal distribution pattern. An optimal distribution maximizes the number of survivors in a food crisis. An optimal system implies that the first response must be to deprive a large segment of the population from access to food stores. This dilemma can be illustrated for India. If agricultural production were eliminated for a year or more and only stored food were available, there would be insufficient food for the entire population to survive for one year (Table 5.17). If only carryovers were available, the full population could be supported for less than one month. An optimal distribution system would feed *only* people that could ultimately survive. Diverting food to others would have the result of decreasing the possible number of survivors. Another aspect of the optimal distribution assumption is that no one could store or use more than the minimum share. Any additional consumption or hoarding would reduce the number of survivors. For example, if only 2% of the Indian population used and stored cereals at the rate of 3,000 kcal $\cdot$ person^{-1} $\cdot$ day^{-1}, the number of survivors after one year would be reduced by 28 million (Table 5.35). Similarly if implementation of an optimal scheme was delayed by 2 weeks, the number of survivors would be reduced by 26 million. The number of survivors would be even lower at higher per capita consumption rates.

5.5 SUMMARY AND GLOBAL ANALYSIS

The analysis of acute-phase food shortage vulnerabilities for 15 countries clearly indicates that in many countries massive levels of malnutrition and starvation are a possible outcome of a major nuclear war. The principal direct cause of such food shortages would be the climatic disturbances and societal disruptions during the initial post-war year. Even without climatic disturbances, import-dependent countries could suffer food shortages. Many of the countries with the highest levels of agricultural production and storage would probably be targets of nuclear weapons. It seems unlikely that food exports would continue from severely damaged countries, thus propagating effects to non-combatant countries. A similar analysis of food storage vulnerability in 130 countries (Figure 5.33), indicates that a majority of people live in countries with inadequate food stores for such major perturbations.

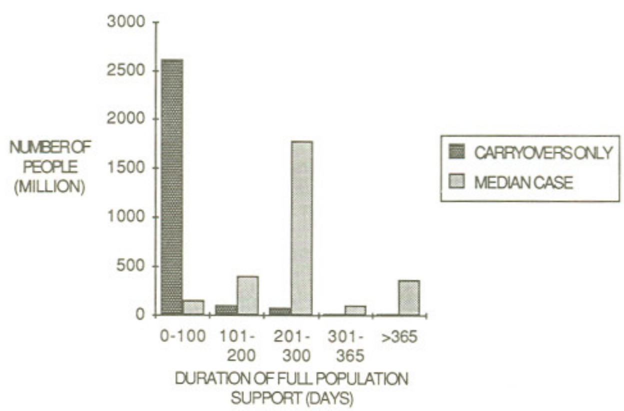

Figure 5.33 Global population at risk of food shortages following a nuclear war

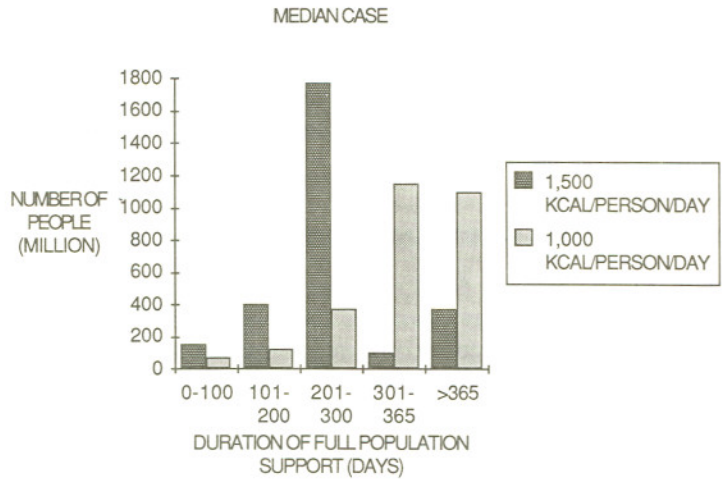

Figure 5.34 Global population at risk of food shortages following a nuclear war, median case.

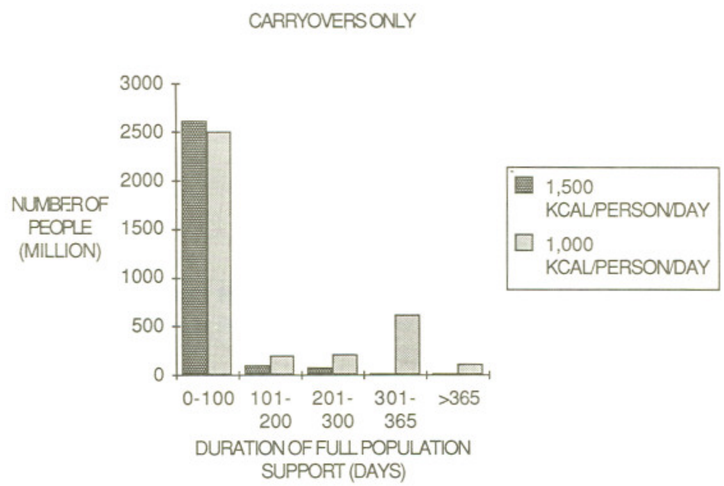

Figure 5.35 Global population at risk of food shortages following a nuclear war, carryovers only.

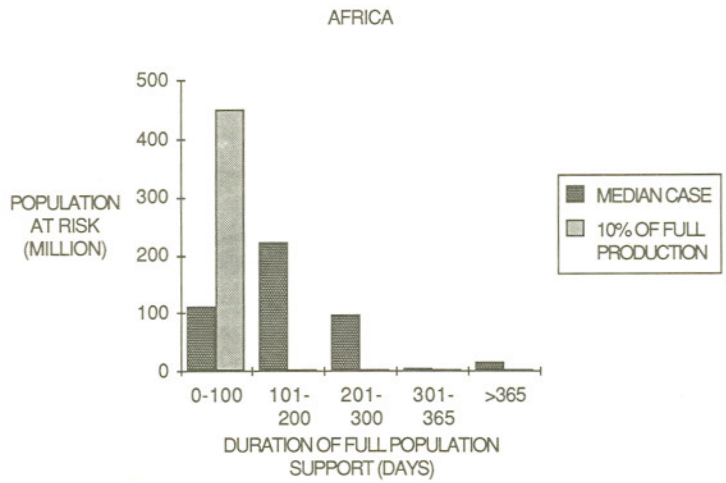

Figure 5.36 African population at risk of food shortages following a nuclear war

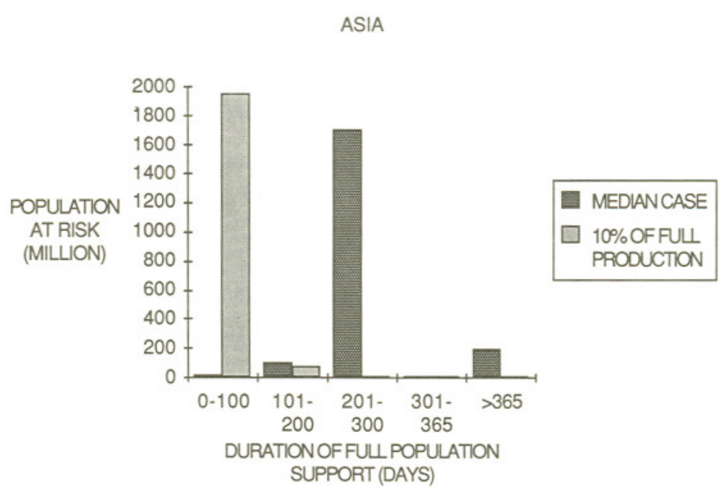

Figure 5.37 Asian population at risk of food shortages following a nuclear war

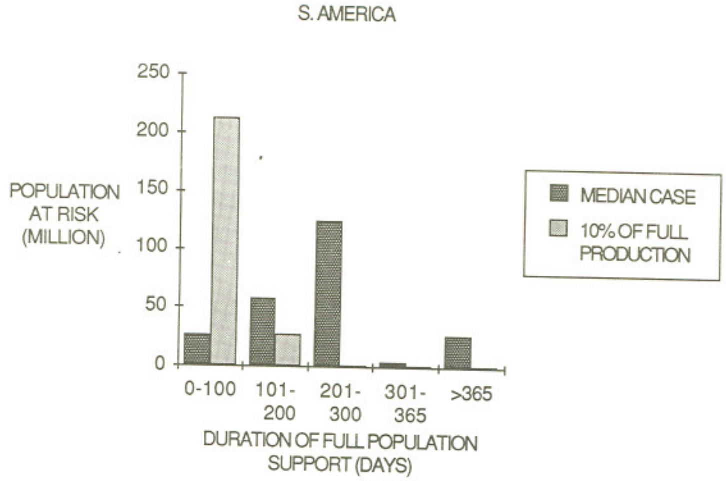

Figure 5.38 South American population at risk of food shortages following a nuclear war

TABLE 5.36

MEDIAN CASE

	Support Duration (Days)	Person-Years (10^6)	1980 Pop. (10^6)	Initial Survivors (10^6)
Argentina	586	43	27	27
Australia[a]	1,211	24	14	7
Brazil	233	78	122	122
Canada[a]	1,935	64	24	12
China[a]	274	559	995	746
Costa Rica	135	1	2	2
India	113	213	685	685
Indonesia	67	27	148	148
Japan[a]	201	32	117	58
Kenya	141	6	16	16
Nigeria	137	29	77	77
Philippines	119	16	49	49
U.K.[a]	382	15	56	14
U.S.A.[a]	1,290	201	228	57
U.S.S.R.[a]	622	113	266	66

[a] Assumed targets, population, and grain stores destroyed in equal proportions.

This is true even if consumption rates of 1,000 kcal•person^{-1}•day^{-1} are assumed rather than 1,500 kcal•person^{-1}•day^{-1} (Figures 5.34 and 5.35).

This vulnerability is particularly severe in Africa (Figure 5.36), Asia (Figure 5.37) and, South America (Figure 5.38). Even though most of the countries of these continents have no nuclear weapons and are not likely to be targeted, the human consequences of a major nuclear war could be nearly as severe as in the principal combatant countries. Few countries would have sufficient food stores for their entire population (Table 5.36), and massive mortality would result if only pre-harvest levels were available (Table 5.37).

TABLE 5.37

CARRYOVERS ONLY

	SUPPORT DURATION (DAYS)	PERSON-YEARS (10^6)	1980 POP. (10^6)	INITIAL SURVIVORS (10^6)
Argentina	66	5	27	27
Australia[a]	566	11	14	7
Brazil	17	6	122	122
Canada[a]	988	33	24	12
China[a]	86	176	995	746
Costa Rica	23	0.1	2	2
India	28	53	685	685
Indonesia	37	15	148	148
Japan[a]	153	24	117	58
Kenya	25	1	16	16
Nigeria	25	5	77	77
Philippines	36	5	49	49
U.K.[a]	136	5	56	14
U.S.A.[a]	579	90	228	57
U.S.S.R.[a]	98	18	266	66

[a] Assumed targets, population, and grain stores destroyed in equal proportions.

These conclusions represent an aspect of nuclear war that has only been recently realized. The possibility of climatic disturbances following a large nuclear war has introduced a new element to the global consequences expected. Not only are the populations of the major combatant countries at risk in a nuclear exchange, but also most of the global human population. Further, the stresses and problems of the agricultural and food supply systems are not limited to first year following a war. Many countries could experience decreased levels of production, even with no additional climatic effects (Table 5.38).

A similar conclusion was reached in an independent Soviet analysis of

TABLE 5.38

VULNERABILITY OF AGRICULTURAL PRODUCTION DURING THE CHRONIC PHASE[a]

(ALL CASES INCLUDE ENERGY-SUBSIDY FACTORS)

	No Climate Effects	Moderate Climate Effects	Severe Climate Effects
Argentina	N-L	N-L	L-M
Australia	N M-H[b]	L	M
Brazil	L	L-M	M
Canada	M-H[b]	H	H-VH
China	N-L M[b]	M	H-VH
Costa Rica	L-M	L-M	M-H
India	L-M	M	H-VH
Indonesia	N-L	L-M	M-H
Japan	M M-H[b]	M-H	H-VH
Kenya	L-M	M-H	H-VH
Nigeria	N-L	L	L-M
Philippines	L-M	L-M	M-H
U.K.	M-H[b]	H	H-VH
U.S.A.	M-H[b]	H	H-VH
U.S.S.R.	M-H[b]	H	H-VH

[a] N = None; L = Low; M = Moderate; H = High; VH = Very High Effects.

[b] Assuming nuclear targets.

chronic phase post-war food supply problems (Svirezhev et al., 1985). This analysis was based on losses of energy subsidies (technological simplification) and altered patterns of international trade. Assuming a minimal caloric supply rate of 1,900 $\text{kcal} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$, the post-war population support potential of developing countries would be reduced substantially. Africa for example, could only support 67% of the 1980 population following a nuclear war (Svirezhev et al., 1985). This conclusion supports the analysis and ranges presented for chronic-phase population levels in Nigeria and Kenya. As the population and levels of agricultural energy subsidies continue to increase during the remainder of the century, food supply vulnerabilities will increase in developing countries (Svirezhev et al., 1985). If in addition to the import and subsidy losses, climatic disturbances of the chronic phase were severe, only a small fraction of the current world population could expect to survive a few years after a nuclear war.

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