Nuclear Winter: Shutting Down the Farm?

Even a mild 'nuclear winter' could have devastating ramifications for feeding those who survive a nuclear war

"[T]he mechanism most likely to lead to the greatest consequences to humans from a nuclear war is not the blast wave, not the thermal pulse, not direct radiation, nor even fallout; rather, it is mass starvation."

—Environmental Consequences of Nuclear War, Vol. 2: Ecological, Agricultural and Human Effects

By JANET RALOFF

Even if as many as 1 billion people in the Northern Hemisphere were killed outright as a result of a massive nuclear exchange between warring superpowers, *four times* that number would probably survive globally, according to Mark Harwell, associate director of the Ecosystems Research Center at Cornell University in Ithaca, N.Y. And what awaits those survivors can be predicted only by analyzing how natural ecosystems and agriculture would respond to nuclear-war-initiated stresses.

Indirect effects of a strategic nuclear war are likely to be far more consequential, killing far more people, than would be the direct effects of nuclear salvos lobbed between combatants, says Harwell. He believes the significance of these indirect effects has been widely overlooked until now because earlier analyses have largely ignored the far-ranging biological implications of nuclear war.

In June 1982, the Scientific Committee on Problems of the Environment (SCOPE) concluded that "the risk of nuclear warfare overshadows all other hazards to humanity and its habitat." Three months later, SCOPE's parent organization, the Paris-based International Council of Scientific Unions (of which the U.S. National Academy of Sciences is a member), asked its board to investigate these effects. It also commissioned "an unemotional, nonpolitical, authoritative and readily understandable statement of the effects of nuclear war — even a limited one — on human beings and on other parts of the biosphere."

At the sixth SCOPE general assembly, convened this week in Washington, D.C., that report was unveiled. Volume 1 deals with physical and atmospheric effects. Volume 2 covers biological effects and was prepared by Harwell with Thomas Hutchinson of the University of Toronto's Institute for Environmental Studies. What emerges, particularly from Volume 2, is a new perspective on the fragility of the agricultural systems that feed our planet.

"We've placed particular emphasis on agricultural systems because they're both the most sensitive and the most important to humans," Harwell explains. The consensus of the 200 or so biologists who contributed to the SCOPE study in 11 regional workshops over the past two years is that, even in the best of times, natural ecosystems could never feed earth's roughly 5 billion people. They're just not efficient enough. But through subsidies of energy and fertilizers, and by providing protected — some would say artificial — environments, agriculture has expanded the human-carrying capacity of the planet. "Indeed," the SCOPE study says, "without any agricultural productivity, at least 90 percent to 99 percent of the current human population could not be maintained indefinitely."

Yet the predicted combination of acute and chronic climatic disruptions that could be initiated by even a 5,000-megaton nuclear exchange directed at cities and high-value military targets (like missile silos) suggests, according to SCOPE, "at least the possibility of little or no agricultural productivity on up to a hemispheric scale" in the first year after a nuclear war. Moreover, the report notes that a "severe reduction in agricultural productivity" could extend into succeeding years — even if dramatic, adverse climatic effects did not.

As a result, the report says, starvation may be the single greatest cause of death following a nuclear war.

Previous analyses of nuclear war's implications for agriculture have tended to focus on the dramatic cooling — the so-called "nuclear winter" — that could occur in the northern midlatitudes, where fighting would most likely be concentrated (SN: 11/12/83, p. 314). For example, the TTAPS study authored by Cornell astronomer Carl Sagan and his colleagues suggested that temperatures could plummet almost 35°C within just a few months of the closing salvos in a 5,000-megaton strategic nuclear battle. What the new SCOPE analysis graphically portrays is that such massive temperature drops are not necessary to wipe out agriculture for a year in the northern midlatitudes.

An average temperature drop of just 2°C throughout the growing season would be enough to halve wheat production throughout Canada and the Soviet Union — currently two of the world's leading producers of that grain. A 2° to 5° average temperature decrease could lower corn yields throughout the Northern Hemisphere, wiping them out in northern reaches. And a one- or two-day nonfreezing cold spell, if it occurred at a particularly sensitive phase of the growing season, might be enough to eliminate rice yields.

Cereal grains such as these are important because they make up about 70 percent of the world's food energy. Their vulnerability stems from the fact that, like most other agricultural crops, they derive from tropical or subtropical species. This

makes them sensitive to even brief cold spells, to drought, to nutrient deprivation and to low light levels.

Through agriculture, humans engineer an ideal environment for these crops. They reduce competition from other plants, supplement nutrients and moisture, protect them from pests, breed strains for characteristics that adapt them to specific field conditions, and shield them against predictable weather hazards.

But the SCOPE scientists suspect that maintaining that ideal environment, particularly in much of the Northern Hemisphere, would be impossible after a major nuclear war. Reduced temperatures, they say, would be the major reason.

Though freezing is normal over most of earth's surface, to survive cold weather plants generally require a period of gradual exposure to cold — a phase known as "hardening." That's why an unseasonable cold snap can be so deadly; it hits unhardened plants. And climatological forecasts of nuclear-war-induced temperature changes indicate that, depending on when the war broke out, summer freezes might occur.

However, freezing isn't necessary to kill agricultural production. Data published earlier this year by R. Hodgins and R.B. Van Huystee in the CANADIAN JOURNAL OF BOTANY show that maize (corn) seedlings exposed to 12°C for just six days are unable to synthesize chlorophyll, even under full light. "Thus," SCOPE reports, "chilling at a temperature as high as 12°C causes potentially debilitating metabolic disorders." Previously, M. Crèvecoeur and colleagues have shown that while a six-to-eight-day chill can injure the ability of germinating corn kernels to grow; a month-long chill can kill.

But freezing could occur, either as a result of a war breaking out during a growing season, or as a carryover from a prolonged fall/winter war into the next growing season. "The crucial survival factor for many organisms would be whether they were dry or wet, growing or dormant at the onset of nuclear-war-induced climatic extremes," the SCOPE report says.

Tomas Sennett/World Bank

Its popularity in Asia, the tropics and the Southern Hemisphere suggests that rice could be the major grain for survivors in noncombatant countries. Ironically, SCOPE says, a brief growing-season dip below 15°C could cut rice yields by a third, and an average *seasonal decrease of 1°C might wipe out rice yields entirely.*

As transplanted tropical plants, few agricultural crops have a mechanism for avoiding ice-crystal formation within their cells. In fact, decreasing their water content increases the tolerance of all plants to low temperatures. That's why dry seeds and dormant plants would be among those expected to withstand unseasonable cold best. Another class of potential survivors includes those in ecosystems regularly subjected to major stresses, such as fire, drought, clearance and grazing.

Low light levels could also cause severe agricultural upset. Climate models suggest that during the acute postwar phase of environmental disruption, light might be reduced 90 percent or more in northern midlatitudes. If sunlight at the top of crop leaf canopies were reduced that much, plants would risk not getting enough light to stay above the light-compensation point — the level at which the rate of photosynthesis matches that of respiration.

Citing data presented by J.A. Clark at the SCOPE workshop in Essex, England, SCOPE reports that for most crops that light level is about 10 percent of normal. Light levels below that would eventually force a crop to exhaust its carbohydrate reserves and die.

Moreover, the SCOPE study notes, shaded plants tend to produce less dry matter. That suggests that low light levels would reduce the net primary productivity in surviving plants. Net primary productivity is what agriculture seeks to optimize; it's the amount of energy, or dry organic matter, that allows plants to support not only their own existence but also that of animals and decay organisms.

Another change that climatic disruptions could spring on crops is reduced rainfall. Some projections put possible regional rain shortfalls at 25 to 50 percent. To place that in perspective, the SCOPE study notes that agriculturally productive areas of North and South America, Europe and Asia "experience annual rainfall deviations from normal of less than 20 percent." Only the more arid regions of Africa, the Arabian Peninsula, Australia, the Arctic and the deserts of North America and Central Asia experience deviations as high as 30 percent.

Increases in ultraviolet light (UV) levels, from reduced stratospheric ozone, could become yet another important source of crop stress. How much ozone might be destroyed by nuclear explosions would depend on the yield of individual weapons. Wars involving only small weapons might leave the UV-shielding ozone layer relatively intact. But one scenario examined in Volume 1 of the SCOPE study involves mainly high-yield weapons. Projections based on it suggest that 44 percent of the atmosphere's ozone could be destroyed within six months of the explosions, with a depletion of at least 10 percent persisting three to six years.

The concern is how much UV-B (wavelengths in the 280-to-320-nanometer spectral band) might reach earth's surface. Many organic molecules such as DNA and proteins absorb UV-B, and the photochemical reactions this initiates tend to be damaging. Although plants and animals have defense mechanisms to protect them from the UV levels to which they've adapted, the SCOPE report notes that these might not suffice under significantly increased UV-B irradiation.

UV-B's most important threat to agriculture is that it can inhibit photosynthesis. However, it can also reduce some crop yields and protein concentrations and affect leaf expansion, carbohydrate metabolism, fruit growth and pollen germination. The SCOPE study found that a 40 percent ozone decrease at 45° N latitude (about the latitude of Minneapolis) would increase by 213 percent the biologically effective UV-B, thereby increasing plant damage by 132 percent.

Finally, a whole range of war-related pollutants could affect agriculture, particularly throughout the war zones. Acid precipitation with a pH of 2.4 could rain for weeks over northern midlatitudes. Bomb-initiated fires would fill the air with huge quantities of plant-toxic compounds, including nitrogen oxides, ozone, carbon monoxide and sulfur dioxide.

SCOPE surveyed the range of natural ecosystems to gauge how each might handle the climatological and environmental insults that climate modelers project could occur in the wake of a Northern Hemisphere nuclear war.

In general, the tropics would be most sensitive — particularly to changes in temperature — regardless of when a war occurred. The oceans, as a major store of heat, could withstand great temperature changes but would suffer dramatically from light reduction. Northern temperate regions would suffer more if the war occurred in spring or summer, when actively growing plants are most vulnerable to stress. Australia is not so vulnerable to cold or darkness as it is to water deprivation. Subtropical grasslands and savannas in Africa and South America might be the least affected of terrestrial ecosystems, because their plants are more cold-tolerant and drought-resistant.

"We basically decided," Harwell told SCIENCE NEWS, "that if a war were to occur in the spring or summer in the Northern Hemisphere, essentially all agricultural

production would be shut down for that year" — even if the period of acute cold or climatic change were brief. "If the war occurred in fall or winter, then it would depend on how intense the 'nuclear winter' was," he says. "If you had subfreezing temperatures the following spring or summer, then again you'd have no production."

In fact, the SCOPE report says, "Agricultural production in most of the world would probably be impaired for a period of at least several years after a major nuclear war." It also notes that disruption of world trade in agriculturally important goods and commodities — such as fertilizer, pesticides and fuel for tractors — could further reduce food production. The SCOPE data suggest that a reduction of these subsidies to energy-intensive agriculture, the most productive systems, could in itself account for a 50 percent decline in farm productivity, says Harwell.

But even this does not project where the threat of starvation looms greatest. For that one has to look not only at a region's ability to feed itself but also at how much food it would have in storage when a war broke out. SCOPE scientists analyzed this in depth for 15 representative nations, comprising 65 percent of the world's population, and in a more sweeping way for another 115 nations.

"And the consensus that's coming out of that," Harwell says, "is that there are a few countries — a very few — who have enough stores to keep their post-nuclear-war populations alive indefinitely." These countries tend to be major grain exporters, he says, such as the United States and Canada. Though some of their stores would undoubtedly be destroyed by direct effects of a Northern Hemisphere war, so might up to 75 percent of the population in these two countries. Of the U.S. grain that remained, at least 30 to 40 percent would likely be available throughout the nation, on or near the farms where it was produced — "meaning you wouldn't have to walk all the way from New York to Russell, Kansas, to find some," Harwell says.

"For the vast majority of other countries — and certainly the vast majority of the world's population," he says, "their food stores are measured in periods of much less than one year. Six months or less is typical." If they run out before agricultural production resumes, he says, "people will begin starving."

Indeed, the many nations, primarily in Africa and Asia, that now rely on food imports would probably face mass starvation regardless of whether they were able to regain or sustain full agricultural production. With the sources for roughly 85 percent of the world's grain imports — the United States, Canada and Western Europe — probably unavailable after a nuclear war, major importers would have few places to turn for food to supplement their own domestic production.

Vulnerability of Ecosystems to War-Related Stresses

Adapted from SCOPE data

ECOSYSTEM	Temp. Reductions	Light Reductions	Precip. Reductions	Radiation	UV-B	Air Pollutants	Fire
AGRICULTURE	XL / NO	LO / NO	L / NO	M / NO	LO / NO	M / NO	LO / NO
TUNDRA/ ALPINE	NO / NO	LO / NO	LO / LO	LO / LO	LO / LO	LO / LO	LO / LO
BOREAL FORESTS	M / LO	LO / LO	LO / LO	M / LO	LO / LO	LO / LO	LO / LO
DECIDUOUS FORESTS (TEMPERATE)	M / LO	LO / LO	M / LO	M / LO	LO / LO	M / LO	M / LO
CONIFEROUS FORESTS (TEMPERATE)	M / LO	LO / LO	M / LO	L / LO	LO / LO	LO / LO	M / LO
TROPICAL FORESTS	L / L	LO / LO	M / M	LO / LO	M / M	LO / LO	M / M
GRASSLANDS	M / LO	LO / LO	M / LO	LO / LO	LO / LO	LO / LO	M / LO
LAKES AND STREAMS	M / LO	M / LO	M / LO	LO / LO	M / M	LO / LO	NO / NO
ESTUARIES	M / LO	L / M	LO / LO	LO / LO	M / LO	M / LO	NO / NO
MARINE	NO / NO	L / M	NO / NO	NO / NO	M / M	NO / NO	NO / NO

SUMMER / WINTER

NO—No effect
LO—Low effect
M—Medium effect
L—Large effect
XL—Extremely large effect

Until now, the SCOPE report says, the extent to which nuclear war could jeopardize food and agriculture globally has not been adequately recognized. If 80 percent of the world's population could survive the initial carnage of a strategic nuclear battle, Harwell says, it's important to know whether the net primary productivity of plant systems would be able to sustain them. Biological studies like those surveyed in the SCOPE report are a first step toward learning that, Harwell says. Unfortunately, he adds, there hasn't been nearly enough work in this area.

George Woodwell agrees. Founder and director of the Marine Biological Laboratory's Ecosystems Center in Woods Hole, Mass., Woodwell points out that we still don't know, for example, whether a 0.5° or 1°C change in average temperature might subtly throw affected ecosystems out of kilter. Might it send plants into flower at a time when their pollinators weren't around — so a seed crop never developed? Could it allow predator/prey relationships to get out of balance? Or might a series of unseasonable chills and freeze spells have the same effect, even if the overall *average* temperature remained close to normal?

Woodwell says there is a misconception that humans are so versatile they can readily adapt to climate change — even, perhaps, to a long-term decrease in average temperature of several degrees. Citing research published in the March CLIMATIC CHANGE by Pall Bergthorsson, Woodwell notes that a 4°C average temperature drop in Iceland was enough to reduce net primary productivity in a major agricultural system there by 60 percent. If such a relationship held globally, he says, survivors of a nuclear war might be in trouble, since "50 percent of the net primary productivity of the earth flows to man now as food of some sort."

Writing in *Nuclear Winter,* a 179-page technical support document to the SCOPE project published last year (Springer-Verlag, N.Y.), Harwell points out that this awakening sensitivity to the food/agricultural crisis that would confront postwar planners "has major implications for the nature and efficacy of civil defense policies" and for reestablishing postwar social order.

Thomas Hutchinson, who coauthored the new SCOPE study, suspects it will initiate action in the United Nations. "There's going to be pressure on the superpowers [to limit nuclear weapons]," he says. And, he adds, as more scientific studies lend credence to the nuclear winter concept, superpower-defense analysts are likely to consider nuclear winter's dire forecast of no combatant "winners."

Finally, some food-sufficient nations farthest from the projected line-of-fire — such as Australia and portions of South America — should be able to use the SCOPE findings to prepare for postwar recovery, Hutchinson says. By starting with the stockpiling of food and dry seeds, "they could certainly enhance the number of people who would survive," he suggests. To hedge their bets, he says, astute nations would probably maintain a diverse store of seed varieties, each designed for different growing conditions.

Research needs in the area of nuclear winter biology are still extensive, "but modest in cost compared with climatic evaluations," says Harwell. Yet outside the Soviet Union, he says, in this area "everything that's been done has been pretty much on a voluntary basis." Perhaps as a result of insights gleaned from the new SCOPE study, he says, that will change. □