NUCLEAR FAMINE

Even a "limited" nuclear war would cause abrupt climate disruption and global starvation

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Nuclear Famine

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Acknowledgements

International Physicians for the Prevention of Nuclear War would like to acknowledge years of crucially important work by physicists, biologists, climatologists and other scientists – who have quietly asked, over and over: "What happens to people around the world when nuclear weapons are used in combat?"

We would also like to thank the International Campaign to Abolish Nuclear Weapons (ICAN) for generous financial support.

Design and graphics by Emma Pike
Drawings by Daniel Medina

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Introduction

It's long been known a major nuclear war could destroy modern civilization and kill most of humanity. But what about a "limited" nuclear war – a conflict confined to one region, say, or involving just a tiny fraction of the world's arsenals?

"Famine could result for a third of Earth," the authors write, "even from a war between India and Pakistan using less than 3% of the global nuclear arsenal."

This report summarizes the latest scientific work, which shows that a so-called "limited" or "regional" nuclear war would be neither limited nor regional. On the contrary, it would be a planetary-scale event. In fact, it would be far more dangerous than we understood even a few years ago. A war that detonated less than 1/20th of the world's nuclear weapons would still crash the climate, the global food supply chains, and likely public order. Famines and unrest would kill hundreds of millions, perhaps even billions.

"In a nuclear war, bombs targeted on cities and industrial areas would start firestorms, injecting large amounts of soot into the upper atmosphere, which would spread globally and rapidly cool the planet," according to a landmark study published in August 2022 by *Nature Food*.[1]

Lili Xia at Rutgers University led an international team that examined how much Sun-blocking soot would be generated under various scenarios of a nuclear war between India and Pakistan. They considered how far global temperatures would fall as a result; what would happen to crop production; and finally, how many people would starve to death. Their findings: As horrific as the war zone itself might be, with tens of millions of direct, immediate fatalities, the regional death toll would be dwarfed in coming months and years by starvation deaths all around the world. In fact, they found, more than 2 billion people could die of starvation after an India-Pakistan war.

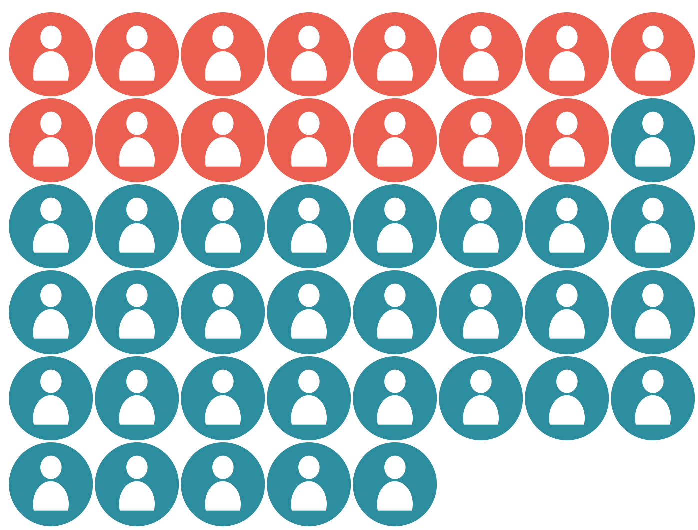
"Famine could result for a third of Earth," the authors write, "even from a war between India and Pakistan using less than 3% of the global nuclear arsenal."

Table 1: adapted from Xia et al, Nature Food, August 2022

Nuclear war scenario	Millions of metric tons (Teragrams) of soot generated	Direct fatalities	Deaths due to famine by the end of Year 2
100 weapons detonated 15 kilotons each	5 Tg	27 million	260 million
250 weapons detonated 15 kt each	16 Tg	52 million	930 million
250 weapons detonated 50 kt each	27 Tg	97 million	1.4 billion
250 weapons detonated 100 kt each	37 Tg	127 million	2.1 billion
500 weapons detonated 100 kt each	47 Tg	164 million	2.5 billion

The five scenarios listed are plausibly in-line with the region's nuclear arsenals. The researchers used a 2010 population dataset that assumed a total world population of 6.7 billion people. (Total world population estimates today are higher at about 8 billion people[2]). The calculated death tolls of up to 2.6 billion people indicate that a nuclear war between India and Pakistan could kill up to every 3rd human.

Using less than 3% of the world's nuclear weapons, a nuclear war between India and Pakistan could kill up to every 3rd person on earth



Again, every one of those scenarios takes as a starting assumption that 97% of all the world's nuclear weapons will *not* be used. The scenarios considered involved a hypothetical nuclear conflict between India and Pakistan – two nations who have fought recent wars, continue to have border skirmishes, and deploy nuclear weapons prominently in their military planning. But the authors of the *Nature Food* study note that it does not necessarily matter where such a war happens. Whether cities and industrial areas are incinerated in the Middle East, on the Indian subcontinent, or in Central Europe, the soot rises into the same sky.

The Years Without Summer

Major explosions and fires can cause severe climate disruptions. The historical evidence for this includes cooling spells after major volcanic eruptions, as well as the catastrophic global cooling after an asteroid strike millions of years ago that killed off the dinosaurs. (Researchers have also studied historical weather data after the massive city fires of World War II but results were inconclusive[3]). The 1815 eruption of the Tambora volcano in Indonesia, the largest eruption in the last 500 years, lofted millions of tons (or Tg, teragrams) of sulfur and ash into the stratosphere. The sulfate aerosol debris drifted around the world, above the rain clouds. A year later it was still there, and 1816 – with persistently overcast skies, crop failures and hunger – became known in the northeast United States as "the year without a summer." Across the Atlantic, in a Europe exhausted by 25 years of Napoleonic wars, a bizarrely wet and cold growing season contributed to famines and a typhus epidemic.[4]

When a nuclear weapon detonates, it briefly creates temperatures four times hotter than at the center of the Sun.

When a nuclear weapon detonates, it briefly creates temperatures four times hotter than at the center of the Sun.[5] A blast over a city can create a firestorm – a massive fire fed by in-rushing winds of hurricane strength. Could a war involving nuclear weapons, by setting fire to multiple cities, bring about a Tambora-level global cooling? For decades now, the major climate models say yes – and in fact they indicate the cooling would be more severe and persistent than that seen after even the most massive volcanic eruptions. Soot from burning cities would be lofted miles above the clouds, blown around the world, and float up there for years. It would blot out the Sun. Temperatures would plummet; crops would fail.

The Rutgers-led international team that modeled expected starvation deaths after a regional India-Pakistan nuclear war has also calculated, for the first time, the deaths that would result from the even worse mass famine that would follow a full-scale nuclear conflict between Russia and the United States. **They estimate that 5 billion people out of 6.7 billion worldwide would be dead within two years.**

This sobering reality has been known since the original nuclear winter studies were conducted in the 1980s.[6,7,8,9] Newer studies[10,11], using more advanced climate models and far more powerful computers, support the predictions made nearly 40 years ago by astronomer Carl Sagan and others: A decade or more of winter would follow a major nuclear war between the United States and Russia. Most of humanity would die.

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This is a newly calculated prediction – three out of every four people in the world, dead in two years. But it confirms a long-standing, uneasy awareness that humanity exists at the pleasure of the Russian and U.S. military bureaucracies. Washington and Moscow may have scaled back their Cold War nuclear weapons arsenals – but those two national arsenals remain enormous, they are again on the rise, and collectively represent more than 90% of the world's nuclear weapons stocks.[12 13]

What about the seven other nations who also hold nuclear arsenals? They are France, Great Britain, Israel, India, Pakistan, China and North Korea. Their second-tier arsenals are small by comparison to the American and Russian Cold War legacy stockpiles. But decade after decade, some of these smaller arsenals have continued to grow. As they've done so, the scientific record has also been growing, building in parallel, study after study, to inform an awakening realization: there is no such thing as a minor or small nuclear weapons arsenal.

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It might be tempting to dismiss Pakistan or France as a mere regional power. But the political leadership of Islamabad and Paris each has enough nuclear explosive power at their fingertips to produce years of global cooling.[14 15] It turns out that virtually any of the nuclear-armed nations can cause immense world-wide suffering, agricultural and societal collapse, and mass death.

For that matter, extrapolating from the data reviewed here, this awesome power is not just in the hands of nine national governments. It is also *de facto* in the hands of many lower-level individuals throughout military hierarchies. Every commander of a U.S. Ohio class or a Russian Borei class submarine has at his disposal firepower comparable to that of an entire nation such as Pakistan or France.[16] There are 14 Ohio class and 5 Borei class submarines in service today.[12 13]

Diving Into the Ominous Science About a "Limited" Nuclear War

In landmark studies published in 2007, climate scientists Brian Toon, Alan Robock and others modeled a hypothetical nuclear war between India and Pakistan.[17] [18] The models assumed each nation used 50 nuclear weapons against the other. For perspective, such a war would have involved less than 0.5% of the world's nuclear arsenals. It would also represent about 1/3rd of Indian-Pakistani nuclear arsenals today.[15] [19] This was an early exploration of what a "limited" or regional nuclear war might look like, and it inaugurated an entire line of scientific inquiry. (See **Table 3**).

The predicted results were global and apocalyptic:

5 Million Tons

More than five million tons (Tgs) of smoke that had once been Karachi or Mumbai would be lifted into the stratosphere and blanket the world in darkness for years to come.

1.3°C

The average global temperature would drop about 1.3°C, and food production would fall.

2 Billion

Up to 2 billion people -- a staggering number, almost every 3rd human -- would be at risk of starvation.

Reviewing the above and related studies [20] [21] [22] [23] for a 2013 briefing paper, International Physicians for the Prevention of Nuclear War and Physicians for Social Responsibility found that up to 2 billion people would be at risk of starvation.[24] At the time, this was almost one third of the world population.

An abrupt cooling event of 1.3°C would be a massive planetary shock. For context, there is widespread international concern about a rise in average global temperature by about 1°C since the pre-industrial era. Nations around the world have pledged enormous resources to try to hold further global warming to no more than 1.5 - 2°C above pre-industrial temperatures.

But that's not the worst of it. The abrupt shock of 1.3°C in global cooling was predicted by narrowly-focused models, which considered only the disruption of Sun-blocking soot. The models were not built to consider a second major consideration: damage to the ozone layer.

Damage to the Ozone Layer

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Ozone is a molecule of three oxygen atoms – O_3 instead of the more commonly known O_2. A layer of ozone molecules encircles the planet about 10-20 miles up, and it shields Earth's surface from ultraviolet radiation. But if massive amounts of post-nuclear war soot rise into the high atmosphere, the soot itself is heated by the same sunlight it blocks off from us, causing local chemical reactions that rapidly degrade the ozone.

A 2008 study led by Michael Mills and a team at the National Center for Atmospheric Research in Colorado modeled the effects on the ozone layer of the same hypothetical scenario – 100 nuclear weapon detonations traded between India and Pakistan – and found that 20% of global ozone would be destroyed. Over the high northern latitudes – including the United States and Canada, Europe, Russia and China – it would be far worse, with 50-70% of the ozone layer destroyed.[23]

A few years later, in 2014, Mills and his team used the latest data to reprise the scenario – 100 nuclear detonations traded between India and Pakistan – and found it would bring ozone losses in the skies above populated areas "unprecedented in human history." (This model, like others, also predicted catastrophic cooling from Sun-blocking soot, with "the coldest average surface temperatures in 1,000 years." Mills and his team predicted surface temperatures would remain reduced for more than 25 years, and "could trigger a global nuclear famine."[25])

The most recent ozone-focused study, published in 2021 and led by another NCAR researcher, Charles Bardeen, relied upon an updated climate and chemistry model to reach a similar conclusion: A regional nuclear war would degrade the global ozone layer by 25%, and the ozone would take at least a dozen years to recover.[26]

With our protective ozone shield down, Earth would be exposed to increased levels of UV radiation. The exact consequences of this have not been calculated. In humans, more UV radiation would be expected to cause more sunburns, cancers, cataracts, immunosuppression, and photoaging (skin damage that includes wrinkles, loss of skin tone, and pigmentation spots). Perhaps more importantly, increased UV radiation would also hinder crop growth – over and above the catastrophic agricultural collapses already predicted by models focused on soot-driven global cooling.

It is a strange paradox that Earth after a limited nuclear war would simultaneously be denied the life-giving warmth of the Sun, even as we'd be more punished by the Sun's harmful UV radiation.

(As Xia and colleagues state in *Nature Food*, "further studies are needed" about many aspects of life after a nuclear war – from UV radiation damage as the ozone layer fails, to radioactive fallout from the war zone itself, to freshwater availability and insect population changes.)

Even without such granular data, the science about the effects of Sun-blocking soot after a limited nuclear war is disquieting.

Even "Small" Wars Bring Unprecedented Crop Failures

A paper in 2020 led by Jonas Jägermeyr, a scientist at NASA's Goddard Institute for Space Studies, used six leading crop models to assess how agriculture would respond to the field's most common hypothetical: 100 smaller (15 kiloton) nuclear detonations in India and Pakistan. (Again: Any number of different "limited" scenarios could be imagined – a war between China and North Korea, say, or perhaps an exchange of nuclear weapons between Russian and NATO forces over Ukraine. Assuming the weapons and targets are of similar size, the consequences would be similar. If scientists have often defaulted to war-gaming India-Pakistan scenarios, that's in part because keeping one variable constant – the war zone – allows for easier comparisons of results across studies.)

In the NASA team's models, 5 Tg of soot resulted in steep global cooling of 1.8°C, and at least five years of bad harvests. Hardest hit were more temperate northern regions, including the United States, Europe, Russia and China, collectively the world's breadbasket. Corn and wheat – two of the world's most important food crops – drop by 13% globally, with "adverse consequences for global food security unmatched in modern history."[27]

> The NASA team's models found steep global cooling of 1.8°C, and at least five years of bad harvests, leading to world hunger "unmatched in modern history".

Scientists working for the U.S. nuclear weapons program at Los Alamos National Laboratories recently published a lonely dissenting view.[28] The Los Alamos team did not make its internal models available for independent review. They addressed the same hypothetical war between India and Pakistan. But they ran their simulations not using a Pakistani or Indian urban area, but a U.S. suburb, for which they included satellite imaging. In a rebuttal, Robock and colleagues note the imaging shows "a target area of suburban Atlanta that includes a golf course, playground, and individual houses with large yards, with little material to burn, which is not representative of densely populated cities in India and Pakistan."[29] Other scientists have calculated the Los Alamos team under-estimated the fuelavailable in those dense Asian cities by at least 10-fold.[30] The Los Alamos model assumed a city fire duration of only 40 minutes, when major World War II city fires lasted for hours or days; did not simulate gas line breaks as seen at Hiroshima; and set various weather and climate conditions that critics say, and the Los Alamos team concedes, prevented the development of firestorms.[29] (The U.S. military does believe in firestorms, and during World War II both accidentally and intentionally created them – most spectacularly in the intentional firestorm created at Tokyo, but also in the bombing of Hiroshima. Despite this, there has been a well-documented, decades-long history of the Pentagon either minimizing or only belatedly appreciating the potential for nuclear weapons-initiated firestorms.[5])

Meanwhile, nature itself seems to have risen up in protest against the Los Alamos claims. In their 2018 paper, the weapons lab team had asserted that soot and smoke from a regional nuclear war would be "highly unlikely" to make it into the stratosphere, "a conclusion supported by examination of … large forest fires." Even as that was being written and published, large forest fires in Canada in 2017, and Australia in 2019 and 2020, were throwing massive amounts of soot high into the stratosphere. The soot and smoke from the Australian bush fires was tracked in the stratosphere for months, in quantities comparable to that seen after a volcanic eruption.[31] Soot from the Canadian fires rose to 12 kilometers as a pyrocumulonimbus – a vertically-developing, fire-fed cloud – but then, as the black soot absorbed sunlight and warmed, it was lofted steadily higher over the next two months, to 23 kilometers.[32] The forest fire observations contradicted Los Alamos, and were consistent with the models of Mills, Robock and other independent scientists.

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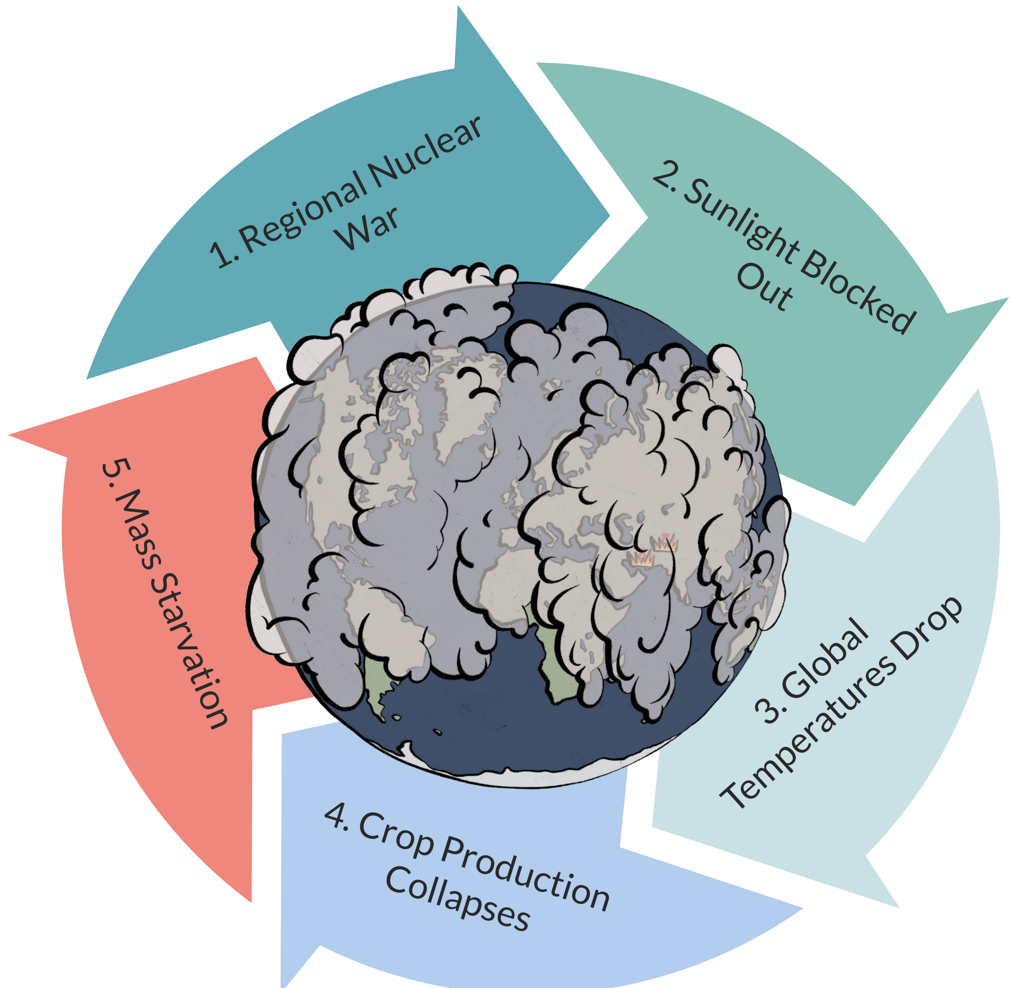
Figure 1: The global catastrophe of a "limited" nuclear war

A "minor" nuclear war might involve 3% or less of world arsenals, but still bring darkness, cooling, crop failures and starvation around the planet.



1 Nuclear War

In an Indian-Pakistani nuclear war, smoke and soot from the nuclear fires rises into the stratosphere. It is lofted around the world and stays there for years.

2 Sunlight Blocked Out

It blots out the sun's warmth, but paradoxically also eats away the ozone layer, which protects life on earth from harmful UV radiation. So Earth becomes colder even as sunlight becomes harsher.

3 Global Temperatures Drop

Global temperatures drop rapidly, erasing all of the recent decades of manmade global warming.

4 Crop Production Collapses

Crop production collapses. Available food calories plummet worldwide.

5 Mass Starvation

Food hoarding and a halt to food exports create public disorder and mass human starvation, on a scale never before seen.

The Science Dives Deeper, as the Arsenals, Cities, and Fires Grow Larger

A macabre question – "how much fuel is there to burn when a city catches fire?" – occurs throughout these nuclear weapon simulations. The "fuel load" is the term for all of the matter that can catch fire after a nuclear detonation, from trees and people to petroleum and plastics. But even as climate scientists and physicists published their papers, they were already outdated, because the cities under consideration had been actively growing in size and complexity. The fuel load was increasing.

The direct consequences predicted in these scenarios would be unprecedented. There would be 50 million to 125 million prompt fatalities – more deaths in hours or days than during all of World War II.

In the 15 years since early studies were published, much has changed. The cities of South Asia have grown a little, providing more fuel to burn in the event they are attacked. Regional nuclear arsenals have also grown. Exact details about nuclear weapons arsenals are closely held secrets. But India and Pakistan are today each believed to have about 150 nuclear weapons ranging in size from 5 to 40 kilotons (kt).[15 19] (China, although not modeled, shares tense borders with both nations and has about 350 nuclear weapons, including some of lower yields, many of 200-300 kt – and a handful of massive weapons of up to 5,000 kt.[33] Nearby North Korea has 10-20 nuclear weapons of unknown size and has detonated a 100 kt bomb.[34])

In a paper published in September 2019, Toon and others simulated a range of new scenarios to take account of these changes. These scenarios involve 250 nuclear detonations – of 15 kt, 50 kt, or 100 kt weapons – and one larger, but still regional, scenario of 500 nuclear detonations of 100 kt weapons.[35] (The most severe scenarios involve more nuclear weapons than India and Pakistan may now possess, but the authors included this in recognition of continued projected growth in national arsenals; and of course, a three-way conflict that dragged in China could easily involve 500 nuclear weapons. Note that even the most severe and speculative scenario would involve less than 4% of the world's nuclear arsenal. See **Figure 2** for a comparison of these scenarios against the explosive power of national arsenals).

Scenario 1:
250 nuclear explosions of **15kt** each

Scenario 2:
250 nuclear explosions of **50kt** each

Scenario 3:
250 nuclear explosions of **100kt** each

Scenario 4:
500 nuclear explosions of **100kt** each

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The impact on climate would also be immense, in all scenarios.

The smallest scenario modeled, an exchange of 250 15 kt weapons, would generate 16 Tg of soot and an average global cooling of 2.5°C. (Remember, the catastrophic scenarios from earlier papers reviewed here, when arsenals were smaller, looked at smaller exchanges of weapons, and predicted about 5 Tg of soot, with cooling of about 1.3°C.)

The larger scenarios are worse. A war using 50 kt weapons would generate 27 Tg of soot and 4.5°C of cooling. A war using 100 kt weapons would generate 37 Tg of soot and 5.5°C of cooling. In the most severe regional Indian subcontinent scenario, a war using 500 nuclear weapons of 100 kt each would generate 47 Tg of soot and 6.5°C of cooling.

Scenario 1:
16 Tg of soot and global cooling of **2.5°C**

Scenario 2:
27 Tg of soot and global cooling of **4.5°C**

Scenario 3:
37 Tg of soot and global cooling of **5.5°C**

Scenario 4:
47 Tg of soot and global cooling of **6.5°C**

For comparison, the last Ice Age, when our ancestors contended with wooly mammoths and saber tooth tigers, was about 6°C cooler than today. Although cooling would be global, the temperature drops across North America, Europe and Asia would be even worse. Global precipitation would decline, and growing seasons would shorten.

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Scientists also continue to model a large-scale U.S.-Russian nuclear war. A paper published in 2019 reviewed simulations by NASA's Goddard Institute for Space Studies that showed such an event would inject not 5 million or 16 million tons of soot – but 150 million tons. The result would, for much of the Northern Hemisphere, be years of below-freezing temperatures in summers.[10] Toon and colleagues, in addition to modeling escalating "limited" wars on the Indian subcontinent, modeled a large-scale U.S.-Russian nuclear war and came to the same conclusions. Xia and colleagues in their August 2022 *Nature Food* analysis calculate the resulting collapse in available calories would, as previously stated, kill the vast majority of the world's people.

Nuclear Famine

After a regional nuclear war, societies everywhere would struggle to adapt to a newly dark, cold, and inhospitable planet. Xia and colleagues writing in *Nature Food* explored this in detail.

They started from the projected soot injections and global cooling predicted by Toon and colleagues in their 2007 and 2019 scenarios, and then simulated the impact of that Sun-blocking soot on yields from wild marine fisheries and from the principal staple crops (rice, wheat, corn or maize, and soybeans).

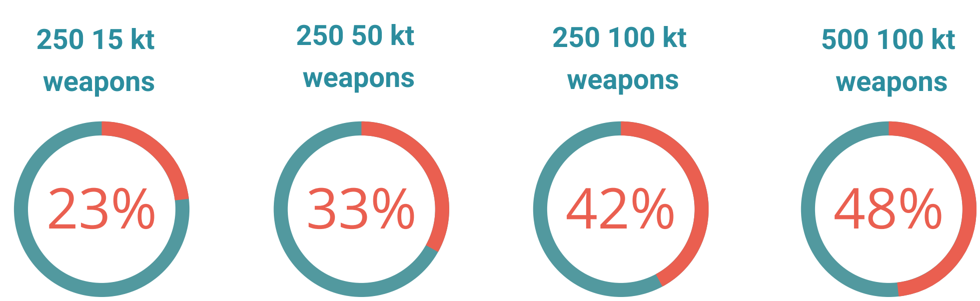
The results: unprecedented global famine. Under every scenario, total available food calories would decline precipitously for the next seven to eight years. Even the smallest scenario modeled would represent the largest drop in global food production since the UN started keeping records. The most severe declines in crop and fisheries production would occur in the upper latitudes of the Northern Hemisphere: Canada, the United States, and much of Europe, Russia and China. (Populations in the Middle East, Africa and East Asia all depend on those regions for food imports.)

For the scenario of an India-Pakistan war using 15 kt weapons, calories from major food crops and fisheries worldwide would fall about 23%. For the scenario involving 50 kt weapons, available calories would fall 33%. For the scenario involving the 100 kt weapons, available calories would fall 41%. And for the extreme scenario of 500 100 kt weapons – again, “extreme” still assumes a purely regional conflict, where the vast majority of the world’s nuclear weapons are not used - the total available calories falls 48%. It is important to note that “available” food is not the same as “accessible” food, the food people are able to put on their table. Especially in times of want, available food is never distributed evenly within or among nations. When it falls even slightly, there is widespread hoarding and price inflation.

For example, during the Great Bengal Famine in 1943, available food decreased only 5% – but panic-buying ensued, food prices soared and 3 million people starved to death.[24] That resulted from a drop in available food of 5%. One can only imagine how unevenly life-sustaining food would be distributed in a world where available food had dropped 23%, 33%, 41% or 48%.

Societies around the world would take desperate measures to adapt. For example, livestock could be killed off *en masse*, both to feed humans in the first year and also to divert animal feed to human consumption; household food waste (around 20% on global average[1]) could be reduced; unpalatable fish species could enter the diet; and international trade might be shut down, as hungry nations seek to prevent food from being exported. Xia and colleagues crunched the numbers for many of these desperate mitigation measures as well. But once the food available in the world drops by ¼ or ½, people starve no matter how wisely they order their affairs.

How much would calories available from major food crops and fisheries **worldwide** fall in each of the below scenarios of an India-Pakistan nuclear war?



What does it mean when total global calories available drop by almost 50%?

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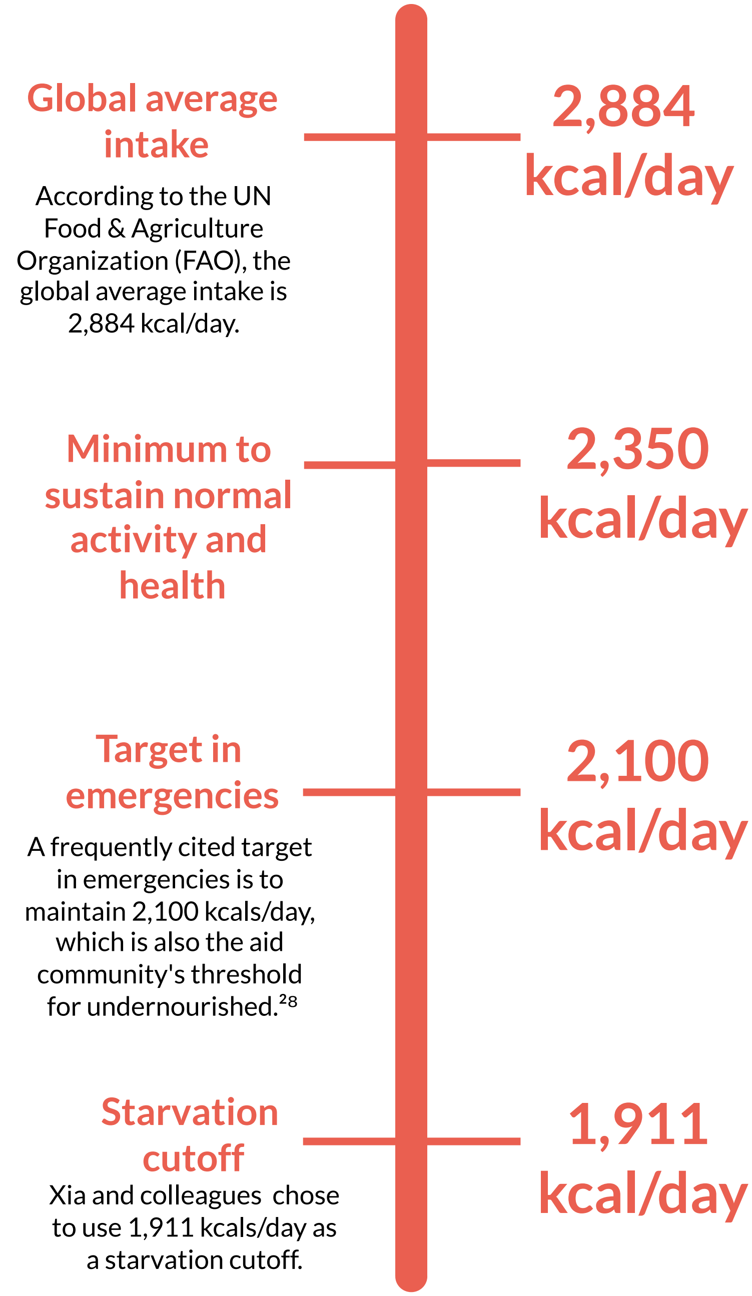
Caloric requirements vary widely depending on a person's age, gender, level of activity, size and underlying medical conditions. According to the UN Food & Agriculture Organization (FAO), the global average intake is 2,884 kcal/day. The minimum to sustain normal activity and health is roughly 2,350 kcal/day; a frequently cited target in emergencies is to maintain 2,100 kcals/day, which is also the aid community's threshold for undernourished.[36]

Xia and colleagues use 1,911 kcals/day as a starvation cutoff. They calculate – not just for the world, but nation by nation – how many people would inevitably end up persistently below that number and so would die of hunger.

It is a nuanced model – as mentioned above, they do consider desperation measures such as eating livestock feed, unpalatable fish and food waste. But as also mentioned, they are only modeling crop failures due to Sun-blocking soot and the associated global cooling. Significantly, they do not consider the effects on available food or human health of radioactive fallout from the nuclear war; or of increased UV radiation from likely ozone damage; or of economic disruptions from any possible breakdown of supply chains or public order. So, the model provides an incomplete picture of the months and years after a regional nuclear war, and if anything may underestimate the ensuing crop failures and mass famine.



That said, the predicted results are frankly horrific. (See **Table 2**).

Xia and colleagues calculate starvation deaths by year two after a moderate-sized "regional" nuclear war – so, a war using a small fraction of massive world arsenals – would kill about 2.1 billion people, many of them half-way around the world from a particular war zone. A larger-sized "regional" war – so, again, a war *not* bringing into play the massive arsenals of the United States or Russia, but using a significant portion of the smaller arsenals of a second-tier nuclear power (such as India, China, Pakistan, Israel, United Kingdom or France) – would kill about 2.5 billion people.

Table 2: Deaths (in millions) by the end of year two after simulated nuclear war scenarios

Assumes livestock has been slaughtered, animal feed diverted to human consumption, and international food trade halted. Does not include deaths related to ozone depletion, radiation or directly from war itself.

Nation (*population in millions in 2010*)	*Prequel scenario:* 100 small (15 kt) weapons are detonated, generating 5 Tg of soot and leads to - 1.3°C of global cooling.	*Scenario 1:* 250 small (15 kt) weapons are detonated, generating 16 Tg of soot, which leads to - 2.5°C of global cooling.	*Scenario 2:* 250 mid-sized (50 kt) weapons are detonated, generating 27 Tg of soot, which leads to - 4.5°C of global cooling.	*Scenario 3:* 250 larger (100 kt) weapons are detonated, generating 37 Tg of soot, , which leads to - 5.5°C of global cooling.	*Scenario 4:* 500 larger (100 kt) weapons are detonated, generating 47 Tg of soot, , which leads to - 6.5°C of global cooling.	*Scenario 5:* A global nuclear war generates 150 Tg of soot, with years of below-freezing temperatures in summers.
Worldwide (6,703)	**335.5**	**1,122.4**	1,579.3	2,238.8	2,675.3	5,413
Australia (22.4)	0	0	0	0	0	0
Austria (8.4)	0	3.1	4	7.4	7.2	8.4
Brazil (195.2)	0	0	0	0	0	54
Canada (34)	0	7.5	29.2	33.6	33.7	34
China (1,367.4)	25.2	558.4	821.9	1,031.9	1,117.3	1,362.3
Finland (5.4)	1.3	5.3	5.3	5.30	5.30	5.30
Germany (83)	0	0	0	61.7	63.9	82.9
India (1,205.6)	0	0	0	0	97.1	731.1
Iran (74.5)	0	5.2	17	20.4	23.5	73
Ireland (4.5)	0	0.6	1	1.7	2.9	4.4
Israel (7.4)	5	5.1	5.2	5.3	5.6	7.1
Italy (60.5)	0.2	5.3	13.3	28.4	26.9	59.4
Japan (127.4)	79.2	102.8	112.2	119.1	121.9	125.6
Kenya (40.9)	5.7	11.6	13.4	16.8	19.9	35.5
Mexico (117.9)	0	18.3	34.9	44.2	61	109.9
Netherlands (16.6)	1.7	7.5	7.5	10.8	13.7	16.5
North Korea (24.5)	6.3	22.2	22.7	24.4	24.4	24.5
Norway (4.9)	3.6	4.7	4.7	4.7	4.7	4.8
Pakistan (173.1)	0	0	0	11.1	14.7	140.4
Poland (38.2)	0	0	0	33.9	32.5	38.1
Russia (143.6)	0	78.4	114.7	125.4	125.8	142
South Africa (51.5)	0	2.1	8	14.1	20	42.8
Sweden (9.4)	1.2	6.7	9.2	9.3	9.3	9.3
United Kingdom (62.3)	0	18.4	26	39	50.5	62.2
United States (312.2)	0	0	0	131.1	217.8	309.6

Adapted from Toon et al 2007, Toon et al 2019, and Xia et al 2022.

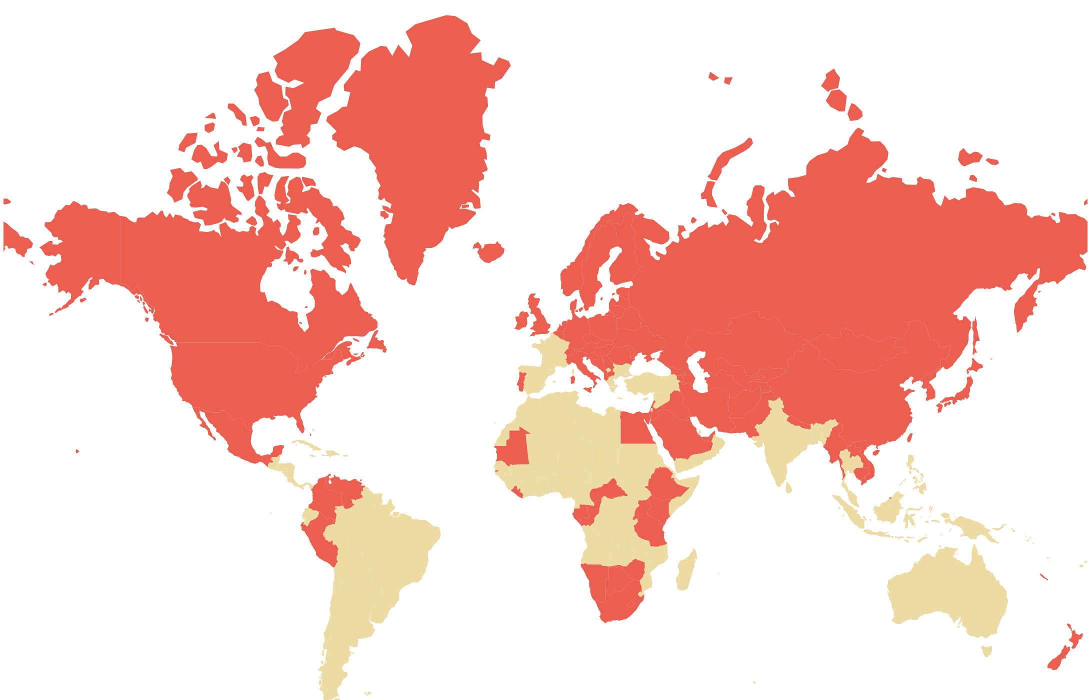
Note the major regional differences in resulting starvation deaths. The strongest caloric reductions due to abrupt cooling after a nuclear war are found over the high latitudes in the Northern Hemisphere. Nations such as Canada, Finland, Norway and Sweden are thus hit hard.

The mid-to-high latitudes including China, Japan, Russia, the United States and Europe also see major drops in food production. But there is less direct effect on local agriculture in more southern nations, including Australia, Brazil, South Africa, India and Pakistan.

It may be confusing to see starvation death tolls of zero for India and Pakistan – in scenarios that model a nuclear war *between India and Pakistan!* How can India and Pakistan do so well, while far-off places like Mexico and Japan are devastated by their war? The explanation is that the model looks at climate-driven change only. The model does not recognize that India and Pakistan may have been lain waste by direct effects of war. (But by the same logic, the model does suggest a comparable-sized war elsewhere, for example a limited NATO-Russia nuclear exchange, would cause less agricultural depression in India and Pakistan than in more northern nations).

There are other nuances. Major agricultural exporters – such as the United States, Canada and Australia – or nations with large livestock populations – again, for example, the United States – are better able to ride out initial shocks by halting all food exports, consuming all livestock, and diverting livestock feed to human consumption. Major agricultural importers ranging from Kenya to Norway suffer correspondingly.

Some nations have such a fortunate combination of location and hardy agricultural products that they seem to ride out even horrific world events. The climate-agriculture model shows Australia in particular tolerates a darker, cooler planet. But again: the model does not account for many impacts, including radioactive fallout from a neighboring war, ozone-layer depletion, and possible ongoing military operations. Moreover, as Xia and colleagues note in *Nature Food*, in the event of worldwide famine, "it is not hard to imagine a flotilla of hungry refugees from Asia and other places heading for Australia and New Zealand."



Countries Most Affected by Nuclear Famine

Highlighted in orange are the countries that would have the most significant rates of death relative to their population. This is based on scenario 3, 250 100k KT weapons. Like the scenarios used in Table 2, this does not include deaths due to ozone depletion, radiation, or directly from war itself.

Minutes Away from Disaster

This paper reviews recent literature on the threat to public health of a regional nuclear war. But there is also a separate and alarming body of literature about how such a war might come about after mere minutes of discussion by world leaders, or even entirely by accident.

Large portions of world nuclear arsenals remain poised for launch within minutes, in response to computer warnings suggesting an incoming attack.[37] [38] This practice has been variously labeled as keeping weapons on high alert status, launch-on-warning status, or hair-trigger alert. In the United States hair-trigger alert has long been criticized as reckless and dangerous not just by academics or peace activists, but in fact by many who have served at the very pinnacle of the national security state.

George W. Bush as a candidate for U.S. president described "high alert, hair-trigger status" as an "unnecessary vestige of Cold War confrontation" that "may create unacceptable risks of accidental or unauthorized launch."[39] Barack Obama as a candidate for U.S. president criticized hair-trigger alert policies as "a dangerous relic of the Cold War" that "increase the risk of catastrophic accidents or miscalculation." After his 2008 election, the President's website declared: "The United States and Russia have thousands of nuclear weapons on hair-trigger alert. Barack Obama believes that we should take our nuclear weapons off hair-trigger alert." [39]

Hair-trigger alert has been called outdated and "absolutely insane" by a former CIA director, and "absurd" by a former NSA director. One former head of all U.S. nuclear forces has testified to Congress that it needs to demand that the Pentagon take the weapons off of hair-trigger alert. Another former head of all U.S. nuclear forces has advised Americans to pray fervently to God that such policies be ended. [39]

Yet U.S. weapons remain on hair-trigger alert to this day. This is so despite multiple near-accidental launches, concerns about the cybersecurity of command and control systems, and a series of horrified U.S. presidents, generals, admirals and intelligence chiefs.

That describes affairs in the United States, a democratic nation that pioneered the nuclear weapon and modern strategic nuclear war theory. But there is no particular reason to believe that nuclear weapons in Russia, India, Pakistan, or anywhere else are managed very differently.

Large portions of world nuclear arsenals remain poised for launch within minutes.

Russia, in fact, not only keeps weapons on hair-trigger alert, but has even built a system code-named Perimeter (more colloquially known as "the Dead Hand"), which responds to a major nuclear explosion in Moscow by assuming it is a decapitation strike from the United States – at which point the Dead Hand launches a retaliatory nuclear strike against the presumed enemy.[40] [41] The system was designed by a top Soviet engineer, Valery Yarynich, who later in life had grave misgivings. As *The Washington Post* noted in Yarynich's 2012 obituary, "He came to doubt the wisdom of maintaining the cocked-pistols approach to nuclear deterrence, the so-called hair-trigger alert … He feared it could lead to an accidental or mistaken launch. … He tirelessly expounded his logic, yet governments were not interested."[41] Nor is Russia likely alone in having an automated last-gasp system. According to nuclear weapons expert Daniel Ellsberg, "There is every likelihood that … Dead Hand systems or arrangements exist in every other nuclear weapons state." [40]

If so, a single nuclear explosion at a national capital such as Islamabad or New Delhi could set in motion events that could kill billions. This could conceivably be triggered by an accident – such as the March 9, 2022, launch by India of an unarmed (but nuclear-capable) cruise missile deep into Pakistan. The Indian defense ministry reported that "a technical malfunction" during "routine maintenance" was behind the event.[42] Had the missile been carrying a nuclear payload, however – or had the Pakistanis assumed the worst – life as we know it might have ended in March 2022, a victim of mere "routine maintenance" of hair-trigger nuclear arsenals.

Figure 2: Comparison of sizes in explosive power

Source: Matt Korda & Hans Kristensen at the Federation of American Scientists

Public Health Assessment

A limited nuclear war would not lead to human extinction. But it would almost certainly be the end of modern civilization. A series of "years without summers", with crop failures, food hoarding and mass starvation, would disrupt everything from international trade to public order. No civilization has ever withstood a shock of such magnitude. There is every reason to expect that the economic, political and technical systems we take for granted would collapse.

Earlier studies – looking at a war using smaller nuclear bombs – suggested up to 2 billion people would be at risk of starvation from the resulting global cooling and crop failures of even a limited regional war.

Xia and colleagues calculate direct fatalities and starvation deaths by year two after a moderate-sized "regional" or "limited" nuclear war – so, a war using a small fraction of massive world arsenals – would kill about 2.2 billion people, many of them half-way around the world from a particular war zone. This is before considering major factors such as economic disruption, ozone layer damage or radiation effects.

The latest studies model increased nuclear explosive power setting fire to larger cities. They still don't consider major factors such as economic disruption, ozone layer damage or radiation effects. Yet even so, their predictions surpass the previous horrific estimates. Xia and colleagues calculate direct fatalities and starvation deaths by year two after a moderate-sized "regional" or "limited" nuclear war – so, a war using a small fraction of massive world arsenals – would kill about 2.2 billion people, many of them half-way around the world from a particular war zone. A larger-sized "regional" war – so, again, a war *not* bringing into play the massive arsenals of the United States or Russia, but using a significant portion of the smaller arsenals of a second-tier nuclear power (such as India, China, Pakistan, Israel, United Kingdom or France) – would kill about 2.6 billion people. (See **Table 2**)

One line of argument holds that things so obviously terrible would never be permitted.

Physicians are used to hearing this sort of magical thinking from patients in denial. In fact, all physicians know that a life-threatening disease such as high blood pressure or colon cancer can be invisible and ignored for years – and that if it is identified it can be treated, preventing a catastrophe.

In the case of a nuclear war, there is no possible treatment after the fact. We must focus on prevention. And the only way to ensure that nuclear weapons are never used is to eliminate them completely. The United Nations Treaty on the Prohibition of Nuclear Weapons, adopted by the UN General Assembly on 7 July 2017 and which entered into force on 22 January 2021, provides the legal and moral foundation for the eradication of nuclear weapons. In the interest of public health, we thus present this summary of important new data about a potential species-level threat to humanity. The cure for this is prevention. The prevention is to renounce and abolish nuclear weapons.

Table 3: Nuclear Famine Studies

Study by Author(s) & Year	Study Design	Summary of Findings
Crutzen and Birks, 1982	Considered possible effects of large-scale city and forest fires after a major nuclear war.	Concluded that potential for large-scale fires with soot production under-appreciated. Predicted ozone layer depletion and global cooling.
Alexandrov and Stenchikov, 1983	Modeled potential climate effects of nuclear war using supercomputers at the Soviet Academy of Sciences.	Found significant and prolonged cooling of northern hemisphere after a nuclear war scenario.
Turco *et al.*, 1983	Modeled potential effects of various nuclear war scenarios on atmosphere and global climate.	"For many simulated exchanges of several thousand megatons, in which dust and smoke are generated and encircle the earth within 1 to 2 weeks, average light levels can be reduced to a few percent of ambient and land temperatures can reach -15° to -25°C." Even "small" scenarios using less than 1% of Cold War world arsenals led to many months of global cooling, with sub-freezing land temperatures even in summer.
Ehrlich *et al.*, 1983	Considered possible effects of large scale nuclear war.	"Subfreezing temperatures, low light levels, and high doses of ionizing and ultraviolet radiation extending for many months after a large-scale nuclear war could destroy the biological support systems of civilization … **extinction of the human species** itself cannot be excluded."
Robock *et al.*, 1984	Considered possible effects of large scale nuclear war.	Found snow / ice feedbacks would make for more prolonged cooling than initially recognized after a major nuclear war.
Pittock *et al.*, 1989	Three-volume, 1,000-plus page compendium of studies to date on atmospheric and other effects of nuclear war.	Large-scale nuclear war would bring years of climate disruption and agricultural collapse. Although tens of millions might be killed in an initial nuclear weapons exchange, **the starvation death toll in coming months and years could be several times greater.**
Toon *et al.*, 2007	Pioneering study into effects of a minor or regional nuclear war, in this case between India and Pakistan. Modeled casualties, damage, radioactive fallout, and smoke production after a regional exchange of 100 nuclear weapons of 15 kilotons. (The 15 Mt total modeled at that time represented 0.1% of world nuclear arsenal explosive power).	**5 Tg of soot would be injected into high atmosphere**. Millions of immediate casualties would occur, rivaling death tolls of all of World War II. Soot in high atmosphere would likely perturb the ozone layer. Radioactive fallout would cause large urban areas to be abandoned for decades.
Robock *et al.*, 2007	Modeled possible effects on climate from the 5 Tg of soot predicted by Toon et al., 2007.	Global average surface **cooling of 1.25 º C persists for years.** More dramatic cooling, of "several degrees Celsius," occurs locally over North America and Eurasia. Global average precipitation declines 10%. "**The cooling in the decade following** [the minor nuclear war scenario] ... is almost **twice as large as the global warming of the past century** ... and would lead to **temperatures cooler than the pre-industrial Little Ice Age.**"
Mills *et al.*, 2008	Modeled possible effects on ozone layer from the scenario of a war using 100 nuclear weapons of 15 kilotons.	Global decrease of 20% of ozone lower. Over high northern latitudes, including Russia, Europe, Canada and United States, 50-70% decrease in ozone layer.
Ozdogan *et al.*, 2012	Modeled possible effects on U.S. corn and wheat production from the 5 Tg of soot predicted by Toon et al., 2007.	Showed corn and wheat production dropping 10% a year on average over 10 years, with peak year decreases of ~ 20%. Did not take into account UV damage from ozone depletion, or effect of daily temperature extremes, on crop yields.
Xia and Robock, 2012	Modeled possible effects on Chinese rice production from the 5 Tg of soot predicted by Toon et al., 2007.	Showed rice production dropping 15% a year on average over 10 years, with average decreases of more than 20% a year for the first 4 years.
Xia *et al.*, 2013	Modeled possible effects on climate and agricultural production in China from the 5 Tg of soot predicted by Toon et al., 2007.	Corn, rice and wheat production would all drop in the immediate year after, by 20%, 29% and 53% respectively. "This reduction of food availability would continue, with gradually decreasing amplitude, for more than a decade ... a nuclear war **using much less than 1% of the current global arsenal could produce a global food crisis and put a billion people at risk of famine.**
Stenke *et al.*, 2013	Used a different climate modeling system in effort to validate or invalidate findings of climate models used by Toon, Robock, Mills to investigate effects of a war using 100 nuclear weapons of 15 kilotons.	In summary, this study, though using a different chemistry climate model, corroborates the previous investigations with respect to the atmospheric impacts.
Helfand, 2013	Literature review of studies to date on effect of a minor or regional nuclear war on global climate and food supplies.	"Significant, sustained agricultural shortfalls over an extended period would almost certainly lead to panic and hoarding on an international scale as food exporting nations suspended exports in order to assure adequate food supplies for their own populations. ... The **number of people threatened by nuclear-war induced famine would be well over two billion**."
Mills *et al.*, 2014	Updated prior models of effects on climate and ozone of a war using 100 nuclear weapons of 15 kilotons.	"Global **ozone losses of 20%–50% over populated areas**, **levels unprecedented in human history**, would accompany the **coldest average surface temperatures in the last 1,000 years**. We calculate summer enhancements in UV indices of 30%–80% over mid-latitudes, suggesting widespread damage to human health, agriculture, and terrestrial and aquatic ecosystems. Killing frosts would reduce growing seasons by 10–40 days per year for 5 years. Surface temperatures would be reduced for more than 25 years ..."
Reisner *et al.*, 2018	Used proprietary (and not broadly available) computer models at Los Alamos National Labs to predict climate effects of a war using 100 nuclear weapons of 15 kilotons.	Computer models of the U.S. nuclear weapons labs **agree that if 5 Tg of soot** are injected into high atmosphere, then climate effects predicted by Robock, Mills, Stenke will occur. They predict less soot will be generated (**3.7 Tg**) and predict it will not rise into the high atmosphere. "Our analysis demonstrates that the probability of **significant global cooling from a limited exchange scenario** as envisioned in previous studies **is highly unlikely, a conclusion supported by examination of** natural analogs, such as **large forest fires and volcanic eruptions.**"
Toon *et al.*, 2019	Updated prior models of effects on climate of a regional India-Pakistan nuclear war, to reflect larger national arsenals and larger fuel loads in the region's megacities. Considered 4 scenarios: Exchanges of 250 weapons of 15 kts, 50 kts or 100 kts each; and exchange of 500 weapons of 100 kts each.	Escalating scenarios led to ever-greater soot injections into the atmosphere of **16 Tg, 27 Tg, 37 Tg** and **47 Tg**, with corresponding global average **cooling of 2.5 º C, 4.5 º C, 5.5 º C, 6.5 º C.**
Coupe *et al.*, 2019	Updated prior predictions of climate effects of all-out nuclear war between Russia and the United States, using NASA Goddard Space Center computer models.	"There is a true nuclear winter … Hard freezes, where temperatures drop below −4 °C, would occur through Years 2 and 3 in the summer, **making it impossible to grow crops in the United States and Russia**. Ukraine, Poland, and Germany would suffer similar fates, while in China, only the southeast part of the country would stay above freezing during the summer."
Jägermeyr *et al.*, 2020	Used NASA computers to model effects on global temperature, precipitation and food production after an India-Pakistan nuclear war using 100 nuclear weapons of 15 kilotons.	Injection of 5 Tg of soot into upper atmosphere would cause an average of 1.8 º C cooling over next 5-10 years, with **decrease in global available average calories from crops of 13%; and of average available calories in 71 most effected countries of > 20%**. This "food supply shock would have **more severe societal implications than any other event documented in recent history**."
Bardeen *et al.*, 2021	Uses an assumed 5 Tg soot load from a regional India-Pakistani war and calculates through a combined climate and chemistry model the effects on the global ozone layer. (Also runs the same simulation for a 150 Tg soot load from a massive nuclear war).	A regional nuclear war would degrade the global ozone layer by 25%, and the ozone would take at least a dozen years to recover. (A massive nuclear war would deplete 75% of the ozone layer, and it would take 15 years or more to recover).
Xia *et al.*, 2022	Modeled effects on agriculture and aquaculture, and worldwide available calories, from each of the escalating regional India-Pakistan nuclear war scenarios described by Toon *et al.*, 2019.	Escalating scenarios led to ever-greater drops in total available calories worldwide of 23%, 33%, 41% and 48%. Worldwide starvation scenarios lead to up to 2.6 billion deaths, most of them from starvation, over the ensuing 2 years. A separately modeled major nuclear war between Russia and the United States led to a drop in worldwide available calories of 81.3% and global deaths of 5 billion, or three people out of four. The study does not consider effects on agriculture or human health from radioactive fallout or increased UV radiation from ozone layer degradation.

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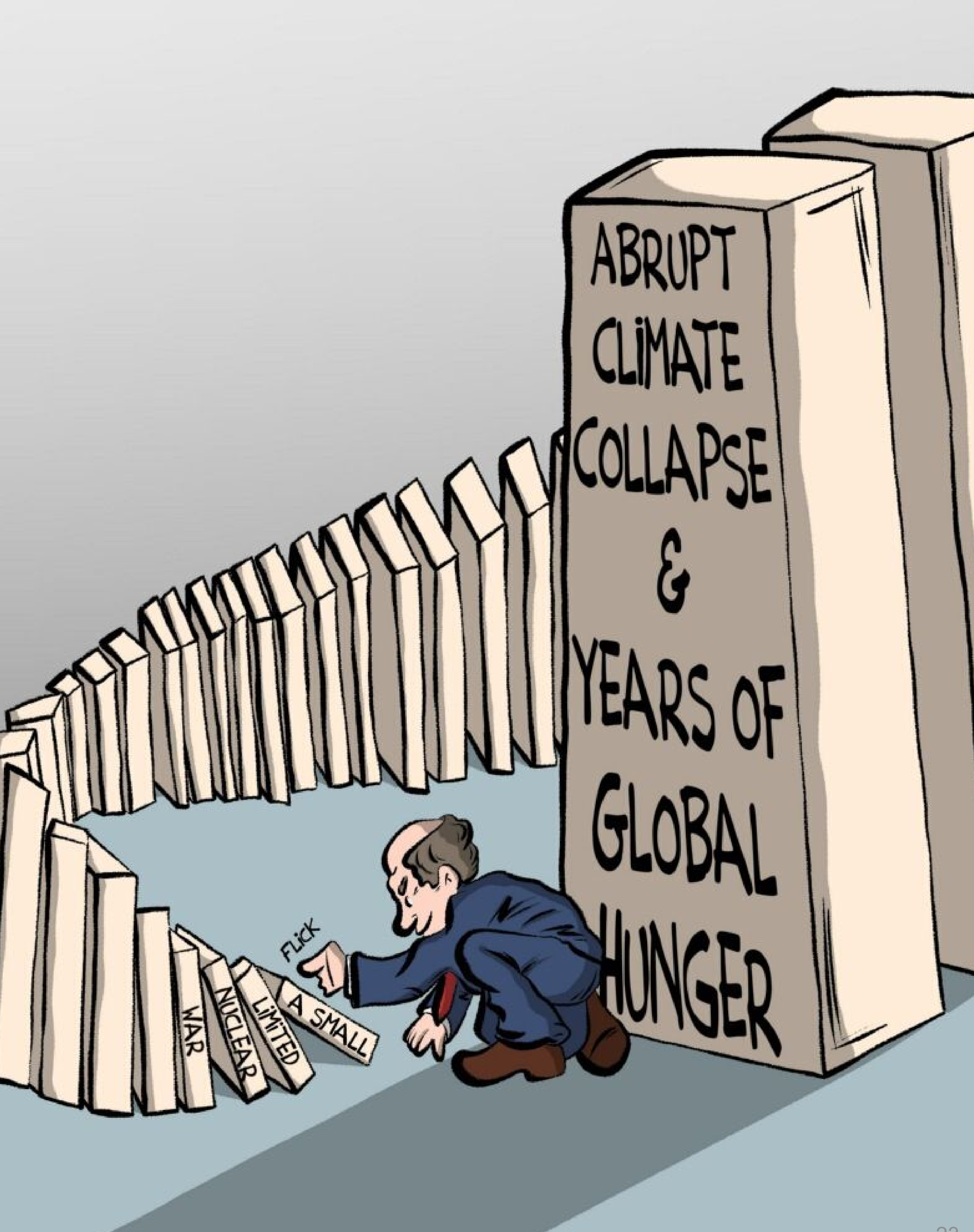
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COLLAPSE
&
YEARS OF
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HUNGER
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