EARLY THOUGHTS

— NUCLEAR WAR, CEREALS AND IDEOLOGY

HOW DOES A FULL SCALE NUCLEAR EXCHANGE WORK ?

— CASE STUDY ON 80s UK

I wrote this essay to understand the scale of the attack in Threads (1984) and also because I feel it's important to have transparent and open debates regarding nuclear weapons. Living in France, a country which possesses nuclear weapons, I'm surprised how easy the debates surrounding nuclear weapons are. The fact is that nuclear weapons are not just "bad", a hypocritical statement made by people who say that while refusing to dismantle them. It was important to discuss it in the most transparent possible way : understand them from a military planner perspective. And what it means is far more problematic than just "bad" : it's an optimization process involving formulas to estimate megatons, maps to assess most destructive attacks, discussion on trade-offs regarding weapons allocation… Cold, bureaucratic and inhumane logic.

A picture from the "Castle Bravo" detonation

According to one of the telexes we saw in the movie, a few minutes before the harvest scene, 17 to 36 million were direct victims of the nuclear exchange. The movie never states how many people died immediately on May 26th 1984 or (1983).

Hiroshima and Nagasaki

In Hiroshima, the death estimates are as low as 90 000 and as high as 166 000, out of a population of 255 000 people. Or 35% to 65% of the population. But we must be careful with such figures, as it's not possible to scale the power of the bomb used at Hiroshima with the modern rates of megaton. Because you cannot scale a death rate of 9300 deaths per kiloton (the Little Boy was 15 KT) to 126 Megaton. It would mean that 126 megatons kills 1 billion people. Because even if we use such a big weapon over a single area, the maximum will still be how many people live there. An increase in blast radius does not necessarily cause scaling of deaths with the same ratio.

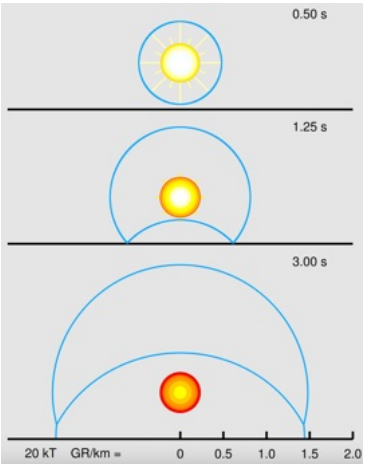
Square Leg

To come back to what could have happened to the UK in case of a nuclear war, we can estimate that 20% to 30% of the population was killed instantly during the nuclear exchange. In the Square Leg exercise (1980), the scenario was 29 million deaths (or 53% of the British population at the time, perhaps 65% of cities population). In my previous post "UK 1984–1985 : fuel crisis and societal collapse", I estimated the range of deaths to 17–20 million (30% to 35% of the population), and all of them in cities (40% to 50% of cities population). Because it's unlikely that the Soviet Union targeted countryside or very small towns, most of the nuclear missiles fall on big cities, at least during the initial phase.

At the time of the movie and Square Leg exercise, something like 30 million people (including metropolitan and/or urban areas) of the urban population was concentrated in 39 cities of economic, strategic, military and political importance. The highest population of these cities was 6.8 million for London (capital) and the lowest was 0.13 million for Oxford (major education center). Killing 20 million people in a single nuclear exchange will require to completely wipe out the entire "core" population of all these cities. If we use the Square Leg estimate, it means that both "core" cities and metropolitan areas were completely destroyed and everyone was killed. A figure that is even more "difficult" to reach because the Square Leg exercise stated that inner London was not directly hit.

On nuclear weapon explosion

While not well-known to the general public, the fact is that there are two ways to detonate a nuclear weapon : a groundburst or an airburst. A groundburst is an explosion close or on the ground to destroy hardened structures like bunkers, silos or airbases. The destruction is more concentrated. On the contrary, airbusts are denotations created at high altitude. Generally used to target troops on the ground, and more especially, cities. Despite being built now with concrete, residential buildings remain highly vulnerable. So, what is expected is large scale destruction. The advantage of an airbust is that the detonation is going to create a massive shockwave across the area. The concept is illustrated with this picture.



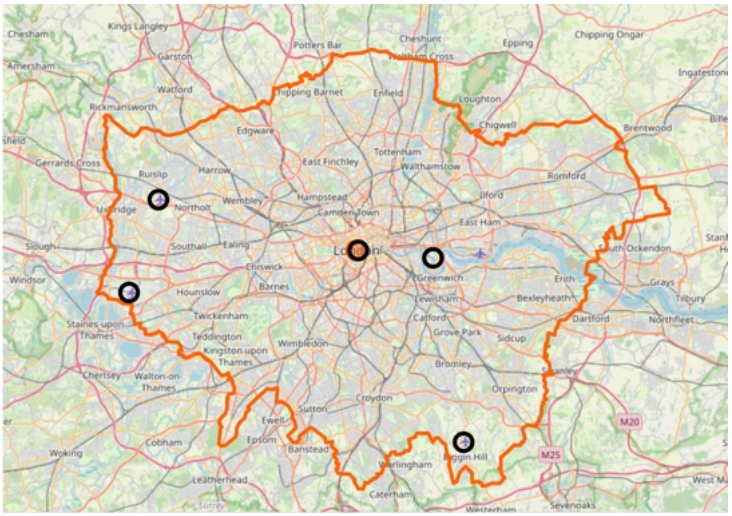
Urban architecture

In the 1980s, major cities in the UK and Western Europe were not isolated and surrounded by empty fields. Most of them were conurbations in fact. It means that when you leave the main city by foot, you immediately enter another urban municipality. It's also important to note that the definition of cities is larger in the UK than in France for example, because it has nothing to do with a peculiar size as the decision to qualify a settlement as a city is up to the Queen or is tied to historical status (like a major church or cathedral for example). That's why you have official cities with as little as 1751 inhabitants (like St Davids). So understanding what kind of cities are going to be hit is important.

The best was done to use figures that truly reflect the effective size of the cities in 80s UK, while avoiding overlapping, overestimating and underestimating. That's why generally the figures used are possibly those of urban areas and some other times those of metropolitan areas, but rarely the figures of the city alone (except from some "isolated" cities like Edinburgh or Aberdeen with few or non-existent surrounding urban settlements). To do so I used a mix of 80s census data (when

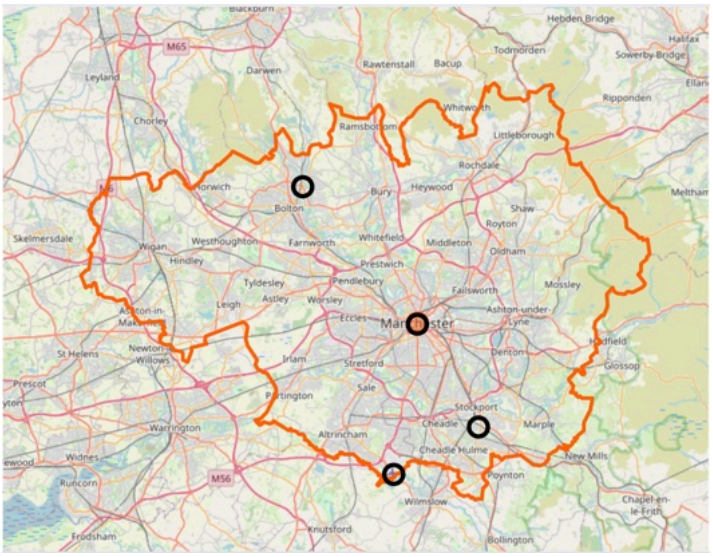
available, and especially for big cities like London where the “borders” were thin) and more modern data. Without doing so would have led to 20–29 million deaths in a single major city (London) with no plausible scenario for the destruction of remaining cities. So the biggest rate for “core” city is 91% for Plymouth with the lowest is Manchester with 23.8% (because the city is part of a major conurbation, and should be accounted as a city inside a larger urban area).

My opinion is that the Soviet Union in Threads won’t just send one nuclear ICBMs in the very middle of a city, because important cities in the UK were in fact conurbations. It’s “safer” to assume that a larger part of the metro and/or urban areas surrounding cities are going to be affected. Here is an example with Greater London showing possible targets (with bombs of different sizes) in the area :



Map credits to “openstreetmap.org”

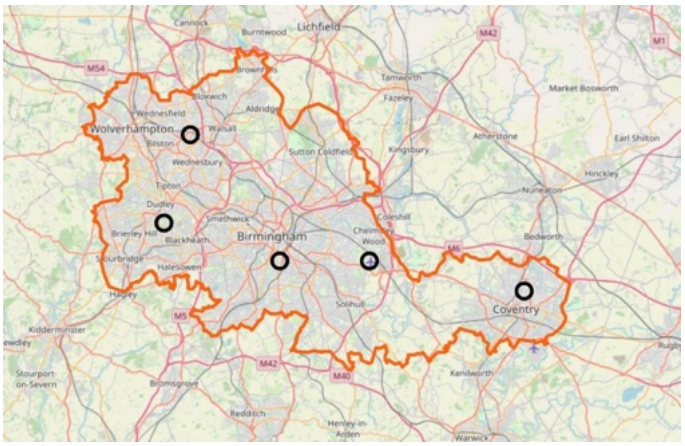
You have one bomb for the center, one for the docklands and three for airports. Here is another example of how many bombs can fall on the Greater Manchester :



Map credits to “openstreetmap.org”

To maximize the destruction on the Greater Manchester area, a bomb is going to fall on the core city of Manchester. But we can also have two bombs for Stockport and Bolton, and another one for the airport. The same logic could be applied to the metropolitan area of Sheffield :

This time, because the conurbation is less tight-knit, we can use bombs (of lower megaton for example) to destroy multiple settlements. One or two on Sheffield, one on Barnsley, one on Wath upon Dearne, one on Doncaster and one on Rotherham. And also one to destroy the Tinsley Viaduct and steel plants. To conclude on this subject, here are some possible targets to destroy the West Midlands conurbations :

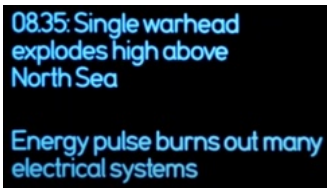


Two bombs hit the core of Birmingham and Coventry, one for the airport and two others to account for the sprawled urban area west of Birmingham. Based on the movie and Square Leg exercise, 210 megatons fall on the UK with an average of 1.5 megaton per bomb. It means that something like 140 bombs fell on the UK. With 20 million deaths, it gives us an average of 143 000 people killed by a bomb. With 29 million deaths, it’s an average of 200 000 people.

Soviet Union in Threads

Even if the Soviet Union is willing later due to the escalation to kill every person in the UK, at the beginning, the bombs are going to hit the UK in the following order (as depicted in the movie) : military targets, major economic, industrial and political centers, then the other cities if needed and only in case of major escalation. The fact that the Soviet Union detonated a nuclear warhead high in

the atmosphere to produce an EMP points to a deadly disruptive attack rather than a genocidal one, at least at the beginning.



Threads don't show it, but what will likely happen at the very same moment is that the Soviet and Warsaw Pact troops (perhaps 0.5 to 1 million soldiers) are going to cross the East Germany borders to enter West Germany, in order to push to the Rhine. It was part of a plan named "Seven Days to the River Rhine" developed within the Soviet leadership.

We can only guess why the Soviet Union launched its attack:

- The crisis may have reached a point of no return, meaning that the leaders of the Soviet Union were unable to back down without incurring huge political costs both at home and abroad, which pushed them into a headlong rush. The growing riots in East Germany mentioned in the film are evidence of this. Retreat after all the force deployments in East Germany would probably have been too costly for the Soviet leadership, as it was at the expense of civilians. The Soviet Union's economy was in total disarray in the 1980s, and this military build-up would have meant more shortages and sacrifices
- Driven by its ideology—an extreme scenario but one that can fit into the logic of the film, which does not justify the attack—the Politburo came to the conclusion that the loss of at least 75 million people in the Soviet Union was acceptable as part of a massive, coordinated plan of attack, if that was the price to pay for hypothetically winning against the United States and keeping the Soviet Union going. An attitude somewhere between madness, cold calculation and sincere belief
- It is also plausible that they reacted to a minor skirmish or provocation (even by mistake), and decided to carry out the plan to invade West Germany as far as the Rhine
- The fact that nuclear bombs were used in the invasion of Iran described at the beginning of the film could have led to a 'normalisation' of the use of nuclear weapons in the Soviet military circles

The fact is that we will never know.

Nuclear exchange begins : military targets and infrastructure

How the nuclear attack is conducted in Threads suggests that something like 30% (or 40 bombs) won't fall on cities because military targets are prioritized. With an average of 1.5 megaton per bomb, it represents 60 megaton. It's also important to account for the destruction of many strategic infrastructures like airports, cargo ports and nuclear power plants. In case of a full scale nuclear exchange in 80s UK, we can imagine the destruction of :

- 10 cargo handling ports
- 12 international or major airports
- 10 nuclear and conventional power plants
- 10 oil refineries

It represents a total of 42 bombs used (or 30%), or 63 megatons. We now have 58 bombs (87 megaton) ready to fall on the biggest cities of the UK. With 20 million deaths, it gives us an average of 344 000 people killed by a bomb. With 29 million deaths, it's an average of 500 000 people.

Next targets : industrial and economical hubs

The idea with these 39 cities was to have a good mix of political, industrial and population hubs. Some cities like London are evident targets, some less obvious cities like Portsmouth which had a small population but was home of a major Royal Navy base. To estimate the deaths, I used the Hiroshima figures incremented by 15% and I split the death rates between core cities and metropolitan areas, or 50% for metro areas to 85% of core cities. The idea behind these figures was to account for the destructive power of modern nuclear weapons, and to account for the reality of urban population. It makes more sense to have more deaths in very dense places and less deaths in more sprawled areas. It's also important to account for the possibilities of "decentralized" targeting over large urban conurbations. The final death rate is a weighted average using the density of the city with the corresponding deaths rates for core and metro areas. Sometimes, you will have some oddities like a death rate of 58.33% for Manchester, against 81.96% for Plymouth. Something that has only to do with the urban and density structure of the city : a small, dense and concentrated city is more vulnerable than a large, unevenly dense and sprawled conurbation.

Estimates

From a military planner perspective, we need a system to produce our estimates : both for casualties and megatons. It could be uncomfortable for people, but the fact is that the process could be optimized by formula (more or less complex) : one for casualties and one for explosive power. This is what we are going to do there. The formula for casualties can be described as this :

- Casualties = ((C × DC) + (M× DM)) / 100
- Let C be the percentage of population in the core area
- Let M be the percentage of population in the metropolitan area (where C + M = 100%)
- Let DC = 85 be the death rate for core areas
- Let DM = 50 be the death rate for metropolitan areas

The formula for megatons can be described as this :

- Megaton = (D / AD) × M
- Let D be the estimated deaths for a city
- Let AD be the average deaths per bomb (either 344,000 or 500,000 in our case)
- Let M be the average megaton value per bomb (1.5 MT)

London and key urban targets

The biggest hit will be for London with death rate reaching 64.88% :

- 4.43 million dead
- 13–19 megaton

Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
London	6,83	42,5	57,50	64,88	4,43	2,40	13,29	19,32

Created with Datawrapper

Even if some levels of devolution exists in the UK, it's still a highly centralized country like most of the Western Europe. The next targets are going to be all the major industrial cities :

- Manchester (textiles)
- Birmingham (automotive)
- Liverpool (major port and manufacturing)
- Glasgow (shipbuilding)
- Leeds (textiles and engineering)
- Sheffield (steel and steel products)
- Newcastle (shipbuilding and steel)
- Nottingham (apparel and medicine)
- Belfast (shipbuilding and textiles)
- Bradford (textiles)
- Stoke-on-Trent (it's a bit of an oddity as it was a city specialized in fine ceramics, but it can still account as a manufacturing center with machines and people)
- Cardiff (steel)
- Portsmouth (port of the Royal Navy)
- Plymouth (shipbuilding)

My guess is that the strikes are going to be more "decentralized" to really hit the infrastructures, but it won't influence the death rate. Here are the figures :

- 10 million dead
- 31–45 megaton

Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
Manchester	2,34	23,8	76,20	58,33	1,36	0,98	4,09	5,95
Birmingham	2,28	46,2	53,80	66,17	1,51	0,77	4,53	6,58
Liverpool	1,95	28,4	71,60	59,94	1,17	0,78	3,51	5,10
Glasgow	1,65	44,7	55,30	65,65	1,08	0,57	3,25	4,72
Leeds	1,48	51,2	48,80	67,92	1,01	0,47	3,02	4,38
Sheffield	1,24	45,6	54,40	65,96	0,82	0,42	2,45	3,57
Newcastle	1,14	35,8	64,20	62,53	0,71	0,43	2,14	3,11
Nottingham	0,73	45,1	54,90	65,79	0,48	0,25	1,44	2,09
Belfast	0,67	58,4	41,60	70,44	0,47	0,20	1,42	2,06
Coventry	0,65	53,8	46,20	68,83	0,45	0,20	1,34	1,95
Bradford	0,52	57,3	42,70	70,06	0,36	0,16	1,09	1,59
Portsmouth	0,48	42,6	57,40	64,91	0,31	0,17	0,93	1,36
Stoke-on-Trent	0,39	69,5	30,50	74,33	0,29	0,10	0,87	1,26
Cardiff	0,31	64,2	35,80	72,47	0,22	0,09	0,67	0,98
Plymouth	0,26	91,3	8,70	81,96	0,21	0,05	0,64	0,93

Created with Datawrapper

Symbolic targets

Two major education centers are going to be hit with the goal to incapacitate the intellectual and research capabilities of the UK : Oxford and Cambridge. And also because these education centers are where most of the British elites are trained. The figures :

- 0.22 million dead
- 0.6–0.9 megaton

Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
Cambridge	0,14	73,6	26,40	75,76	0,11	0,03	0,32	0,46
Oxford	0,13	76,8	23,20	76,88	0,10	0,03	0,30	0,44

Created with Datawrapper

“All out”

Then, what happens is inevitable due to the nature of a nuclear exchange. It becomes an “all out” exchange with many irrelevant targets hit to maximize the destruction in the country and sometimes with no rationale : Leicester, Gloucester, Swansea… The figures for the final bombings are :

- 5–6 million dead
- 15–19 megaton

Key figures

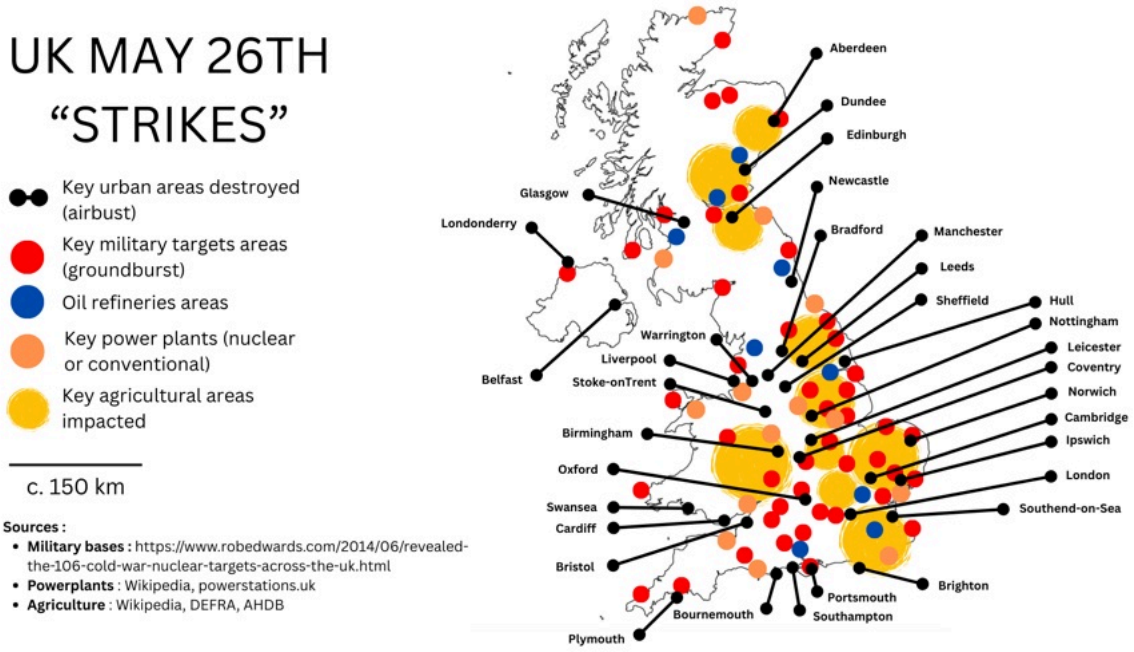
City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
Southampton	0,89	27,3	72,70	59,56	0,53	0,36	1,59	2,31
Bristol	0,58	66,8	33,20	73,38	0,43	0,15	1,28	1,86
Leicester	0,55	67,2	32,80	73,52	0,40	0,15	1,21	1,76
Brighton and Hove	0,55	51,2	48,80	67,92	0,37	0,18	1,12	1,63
Edinburgh	0,53	89,2	10,80	81,22	0,43	0,10	1,29	1,88
Bornemouth	0,39	48,7	51,30	67,05	0,26	0,13	0,78	1,14
Sunderland	0,36	76,4	23,60	76,74	0,28	0,08	0,83	1,20
Kingston upon Hull	0,34	79,8	20,20	77,93	0,26	0,08	0,79	1,16
Luton	0,28	89,2	10,80	81,22	0,23	0,05	0,68	0,99
Reading	0,24	58,9	41,10	70,62	0,17	0,07	0,51	0,74
Swansea	0,24	74,5	25,50	76,08	0,18	0,06	0,55	0,80
Peterborough	0,24	88,3	11,70	80,91	0,19	0,05	0,58	0,85
Aberdeen	0,23	87,4	12,60	80,59	0,19	0,04	0,56	0,81
Warrington	0,21	80,9	19,10	78,32	0,16	0,05	0,49	0,72
Norwich	0,19	64,8	35,20	72,68	0,14	0,05	0,41	0,60
Dundee	0,18	82,9	17,10	79,02	0,14	0,04	0,43	0,62
Swindon	0,18	94,8	5,20	83,18	0,15	0,03	0,45	0,65
Southend-on-Sea	0,18	94,2	5,80	82,97	0,15	0,03	0,45	0,65
Ipswich	0,17	89,2	10,80	81,22	0,14	0,03	0,41	0,60
Gloucester	0,12	92,3	7,70	82,31	0,10	0,02	0,30	0,43
Londonderry	0,11	77,5	22,50	77,13	0,08	0,03	0,25	0,37

Created with Datawrapper

To understand the rationale behind these latest figures, let's imagine that a bomb of any size falls on Buxton (which was not the case in Threads). It has no urban or metropolitan area, so the population of 0.02 million people is concentrated within the core of the city. Even with the biggest death rate, the maximum number of people dying is 16 000 people. Because the biggest cities were already hit, it means that the death rates are applied on smaller and smaller cities, even if the bombs have the same size, leading to a very inefficient use of the megatons. Speaking of "inefficient use" of megatons could seem problematic, but that's how military planners think of nuclear weapons.

End of the day

The lowest estimate is 60 megaton and the highest is 87 megaton (or all available) used to destroy the cities. The total number of deaths is 20 million people by the end of May 26th, with a maximum figure of 39 cities hit. If we try to reach the figures of Square Leg with this model, it means we will need to include 9 million people more. But with only minor settlements left across the UK (or largely below 0.15 million people), and no bombs left, it's impossible. Here is a map to summarize the possible main patterns of bombing in Threads :



At the end of the day, the country is beyond recognition. All critical infrastructures are destroyed. All major urban centers are devoid of life. This is basically what remains of them :

Aftermath of the nuclear bombing at Hiroshima (Photo credit : Mitsugu Kishida)

To summarize all these informations, here is a table :

Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
London	6,83	42,5	57,50	64,88	4,43	2,40	13,29	19,32
Manchester	2,34	23,8	76,20	58,33	1,36	0,98	4,09	5,95
Birmingham	2,28	46,2	53,80	66,17	1,51	0,77	4,53	6,58
Liverpool	1,95	28,4	71,60	59,94	1,17	0,78	3,51	5,10
Glasgow	1,65	44,7	55,30	65,65	1,08	0,57	3,25	4,72
Leeds	1,48	51,2	48,80	67,92	1,01	0,47	3,02	4,38
Sheffield	1,24	45,6	54,40	65,96	0,82	0,42	2,45	3,57
Newcastle	1,14	35,8	64,20	62,53	0,71	0,43	2,14	3,11
Southampton	0,89	27,3	72,70	59,56	0,53	0,36	1,59	2,31
Nottingham	0,73	45,1	54,90	65,79	0,48	0,25	1,44	2,09
Belfast	0,67	58,4	41,60	70,44	0,47	0,20	1,42	2,06
Coventry	0,65	53,8	46,20	68,83	0,45	0,20	1,34	1,95
Bristol	0,58	66,8	33,20	73,38	0,43	0,15	1,28	1,86
Leicester	0,55	67,2	32,80	73,52	0,40	0,15	1,21	1,76
Brighton and Hove	0,55	51,2	48,80	67,92	0,37	0,18	1,12	1,63
Edinburgh	0,53	89,2	10,80	81,22	0,43	0,10	1,29	1,88
Bradford	0,52	57,3	42,70	70,06	0,36	0,16	1,09	1,59
Portsmouth	0,48	42,6	57,40	64,91	0,31	0,17	0,93	1,36
Stoke-on-Trent	0,39	69,5	30,50	74,33	0,29	0,10	0,87	1,26
Bornemouth	0,39	48,7	51,30	67,05	0,26	0,13	0,78	1,14
Sunderland	0,36	76,4	23,60	76,74	0,28	0,08	0,83	1,20
Kingston upon Hull	0,34	79,8	20,20	77,93	0,26	0,08	0,79	1,16
Cardiff	0,31	64,2	35,80	72,47	0,22	0,09	0,67	0,98
Luton	0,28	89,2	10,80	81,22	0,23	0,05	0,68	0,99
Plymouth	0,26	91,3	8,70	81,96	0,21	0,05	0,64	0,93
Reading	0,24	58,9	41,10	70,62	0,17	0,07	0,51	0,74
Swansea	0,24	74,5	25,50	76,08	0,18	0,06	0,55	0,80
Peterborough	0,24	88,3	11,70	80,91	0,19	0,05	0,58	0,85
Aberdeen	0,23	87,4	12,60	80,59	0,19	0,04	0,56	0,81
Warrington	0,21	80,9	19,10	78,32	0,16	0,05	0,49	0,72
Norwich	0,19	64,8	35,20	72,68	0,14	0,05	0,41	0,60
Dundee	0,18	82,9	17,10	79,02	0,14	0,04	0,43	0,62
Swindon	0,18	94,8	5,20	83,18	0,15	0,03	0,45	0,65
Southend-on-Sea	0,18	94,2	5,80	82,97	0,15	0,03	0,45	0,65
Ipswich	0,17	89,2	10,80	81,22	0,14	0,03	0,41	0,60
Cambridge	0,14	73,6	26,40	75,76	0,11	0,03	0,32	0,46
Oxford	0,13	76,8	23,20	76,88	0,10	0,03	0,30	0,44
Gloucester	0,12	92,3	7,70	82,31	0,10	0,02	0,30	0,43
Londonderry	0,11	77,5	22,50	77,13	0,08	0,03	0,25	0,37
Total	29,95	-	-	-	20,09	9,86	60,28	87,61

Created with Datawrapper

Allocation problem

The subject was not discussed earlier, but the allocations of bombs is a critical matter. Because we only have 58 bombs, but 39 cities to hit. It means something like 1.5 bombs per city, but we cannot use a fraction of a bomb. The idea of "optimizing" the destruction of cities could seem unsettling, but this is unfortunately what military planners do every day when they want to find the best way to optimize their weapons. The first thing to understand is that many major and industrial cities were indirectly hit by the targeting of infrastructures, especially the airports and ports (London, Liverpool, Glasgow, Birmingham...). So it could reduce the number of bombs needed to destroy some of the major conurbations. But it doesn't change the fact that we still need a way to efficiently distribute the megatons across cities. This is in fact a very old optimization problem. Here is a table that takes the maximum megaton value per city, and express it as different bombs size :

Key figures

City	Pop	High MT	4,5 MT	4 MT	3,5 MT	3 MT	2,5 MT	2 MT	1,5 MT	1 MT	0,5 MT
London	6,83	19,32	4	4	5	6	7	9	12	19	38
Manchester	2,34	5,95	1	1	1	1	2	2	3	5	11
Birmingham	2,28	6,58	1	1	1	2	2	3	4	6	13
Liverpool	1,95	5,10	1	1	1	1	2	2	3	5	10
Glasgow	1,65	4,72	1	1	1	1	1	2	3	4	9
Leeds	1,48	4,38	0	1	1	1	1	2	2	4	8
Sheffield	1,24	3,57	0	0	1	1	1	1	2	3	7
Newcastle	1,14	3,11	0	0	0	1	1	1	2	3	6
Southampton	0,89	2,31	0	0	0	0	0	1	1	2	4
Nottingham	0,73	2,09	0	0	0	0	0	1	1	2	4
Belfast	0,67	2,06	0	0	0	0	0	1	1	2	4
Coventry	0,65	1,95	0	0	0	0	0	0	1	1	3
Bristol	0,58	1,86	0	0	0	0	0	0	1	1	3
Brighton and Hove	0,55	1,63	0	0	0	0	0	0	1	1	3
Leicester	0,55	1,76	0	0	0	0	0	0	1	1	3
Edinburgh	0,53	1,88	0	0	0	0	0	0	1	1	3
Bradford	0,52	1,59	0	0	0	0	0	0	1	1	3
Portsmouth	0,48	1,36	0	0	0	0	0	0	0	1	2
Stoke-on-Trent	0,39	1,26	0	0	0	0	0	0	0	1	2
Bornemouth	0,39	1,14	0	0	0	0	0	0	0	1	2
Sunderland	0,36	1,20	0	0	0	0	0	0	0	1	2

Of course, this isn't exactly the reality. In fact, because of the technical requirement to create such precise weapons, and because a country can't create all possible kinds of nuclear weapons, the yield values are more arbitrary. If we try to have every possible yield value, it will require to have as many different launching systems. As an example, the US B16 Mod-3 can only have the following values : 0.3, 1.5, 60 or 170 KT. The idea is to cover most of the possible usage but not all of them (which is impossible). The same idea applies to bombs expressed as megatons.

And here is a possible use of all the bombs. You will notice that even if we want to use as much megaton as possible, what we can do is constrained by the finite size of the stock, and the impossibility to use weapons that don't fit the yields :

Key figures

City	Pop	High MT	4,5 MT	2 MT	1,5 MT	1 MT	0,5 MT	Bombs
London	6,83	19,32	4	-	-	-	-	4
Manchester	2,34	5,95	-	1	2	-	-	3
Birmingham	2,28	6,58	-	2	-	1	-	3
Liverpool	1,95	5,10	-	2	-	-	-	2
Glasgow	1,65	4,72	-	-	2	1	-	3
Leeds	1,48	4,38	-	2	-	-	-	2
Sheffield	1,24	3,57	-	1	-	1	1	3
Newcastle	1,14	3,11	-	-	2	-	-	2
Southampton	0,89	2,31	-	1	-	-	-	1
Nottingham	0,73	2,09	-	1	-	-	-	1
Belfast	0,67	2,06	-	1	-	-	-	1
Coventry	0,65	1,95	-	-	-	1	1	2
Bristol	0,58	1,86	-	-	-	1	1	2

Regarding some "sub-optimals" scenarios, it's important to remember that my model split the bombs between the military targets (40 bombs), the infrastructures (42 bombs) and the cities (58 bombs). Unfortunately, many of these infrastructures and military targets are within cities. It means that an optimization process could occur to increase the number of bombs available if we account for the destruction of critical infrastructures within several cities. Here is a table that summaries this issue :

Key figures

Cities	Bombs	Deduced	Used	Notes
London	4	2	2	Heathrow and Biggin Hill airports
Manchester	3	1	2	Manchester airport
Birmingham	3	1	2	Birmingham airport
Liverpool	2	2	0	Liverpool port and airport
Glasgow	3	1	2	Glasgow airport
Southampton	1	1	0	Southampton airport
Belfast	1	1	0	Belfast airport and port
Coventry	2	1	1	Coventry airport
Edinburgh	2	1	1	Edinburgh airport
Portsmouth	1	1	0	Military base and port
Cardiff	1	1	0	Cardiff port
Luton	1	1	0	Luton airport
Plymouth	1	1	0	Military base and port
	25	15	10	-

Created with Datawrapper

Our estimates compared to NUKEMAP

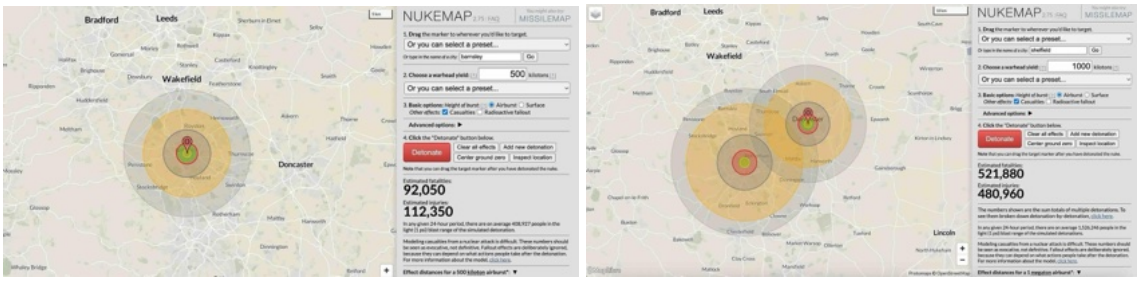
In a Medium post named "*A comparative study on mainstream nuclear war models : case study with NUKEMAP, NWS, Lili Xia et al (2022)*", I tested some of my estimates (weapons allocation) against several cities used in this work with NUKEMAP visualization tool. All explosions are airbusts. As a reminder for estimates :

Key figures

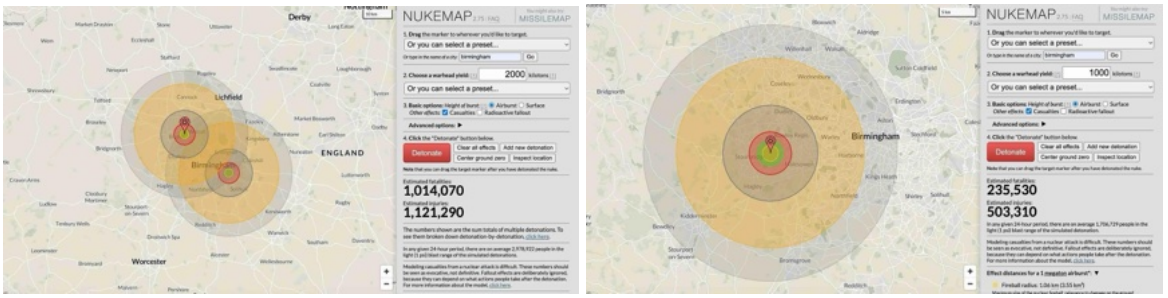
City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
Birmingham	2,28	46,2	53,8	66,2	1,51	0,77	4,53	6,58
Sheffield	1,24	45,6	54,4	66,0	0,82	0,42	2,45	3,57
Coventry	0,65	53,8	46,2	68,8	0,45	0,20	1,34	1,95
Bornemouth	0,39	48,7	51,3	67,0	0,26	0,13	0,78	1,14
Plymouth	0,26	91,3	8,7	82,0	0,21	0,05	0,64	0,93

Created with Datawrapper

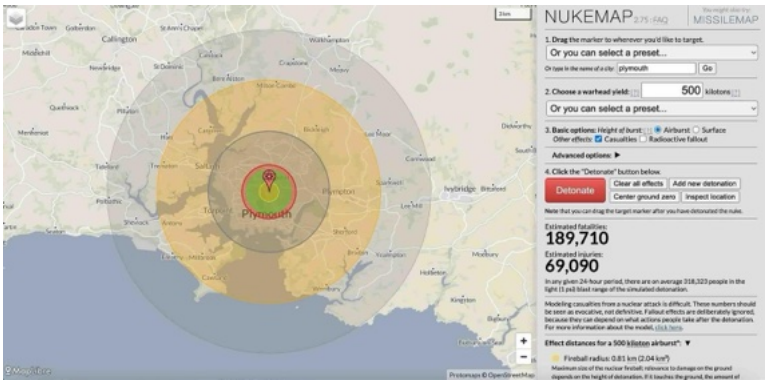
Here are the results for Sheffield :



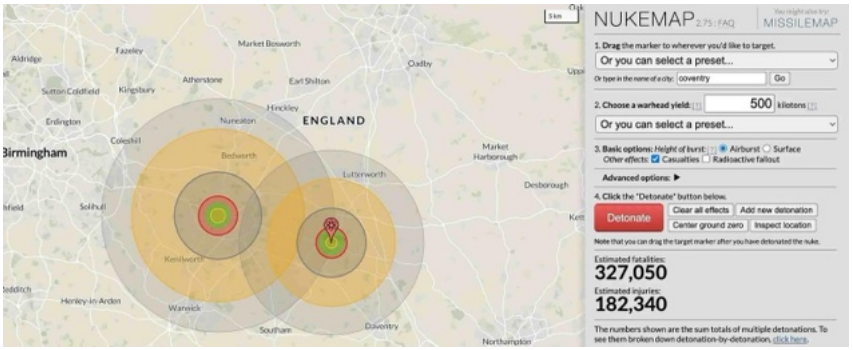
The total of deaths reached 613 000 (76% of my 800 000 estimates with my model). Same with Birmingham :



Deaths estimates reach 1.2 million (80% of my 1.5 million estimates). Here are the results for Plymouth :

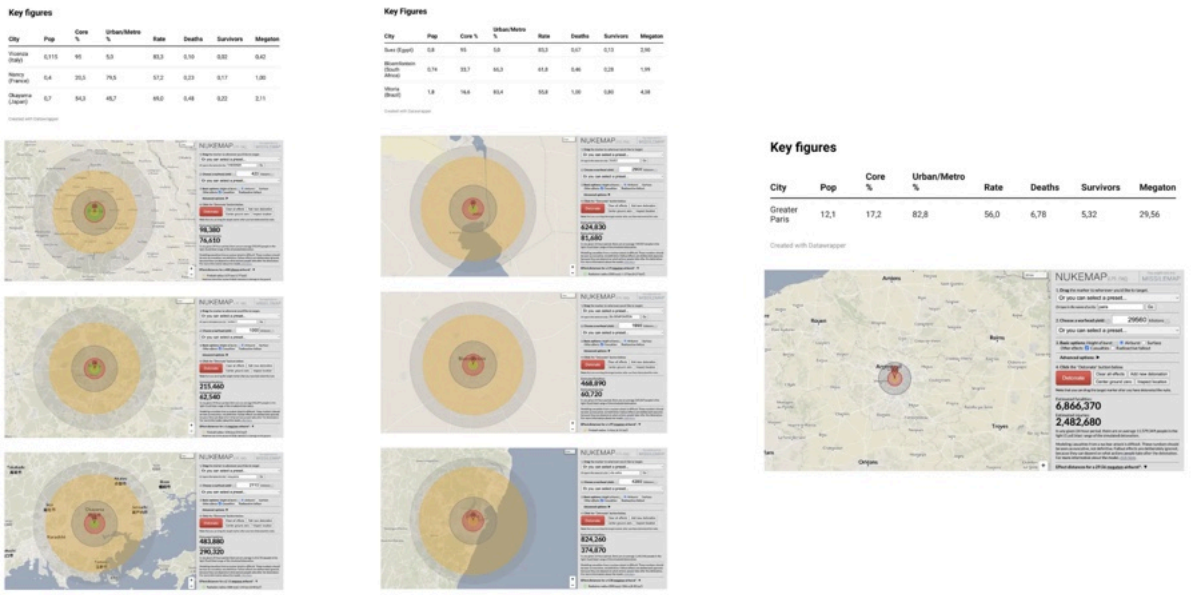


The results are pretty close (90% of my 210 000 deaths with my estimates). Here is what happens with Coventry :



The total of deaths reached 327 000 deaths (72% of 450 000 deaths with my model). And finally, with Bournemouth :

The similarity is striking (83% of 260 000 deaths with my model). Regarding what I said earlier on the “megaton estimates” formula, the consistency of the results are also noticeable when tested over cities not included in my work; and even cities outside the UK. A few examples worldwide :



Without exploring the topic further, there seems to be some kind of relationship between a 1.5 MT weapon (the average used in my calculations) and the idea that 344 000 people (the average deaths per bomb) can be impacted. This formula, with the “casualties estimates” formula, seems to capture the relationship between : urban architecture, casualties and required explosive power. Regarding the problem explained earlier with diminishing yield return, you have the example with the Ile de France region (or Paris metropolitan area). As you can see, if a single weapon can cause the expected damages, the fact is that this amount can’t cover the whole area in a single strike. And also more important : this kind of weapon doesn’t exist in our arsenal.

On MIRV

MIRV (for multiple independently targetable reentry vehicles) is the modern standard for nuclear weapons. A rocket equipped with several small nuclear weapons (generally in the hundred kilotons range) with the aim to create non-linear destruction patterns. Rather than using a single large weapon

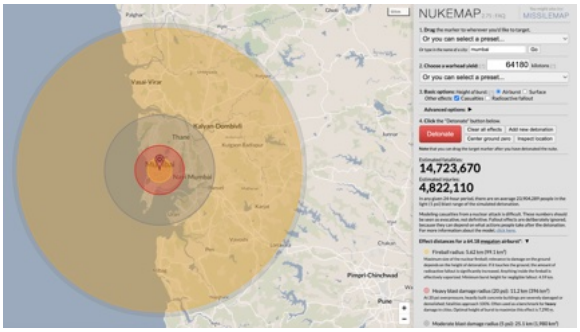
to blow the center of a city, for example, several smaller weapons are used across the urban area to create “pancake-like” patterns of destruction. One of the questions arising with MIRV is : are several small weapons far more efficient than a large weapon ? For the case study, we will try out a small experiment in Mumbai. More than 20 million people live in Mumbai (core and metropolitan area). Using our formula, what is required is the following :

Key figures

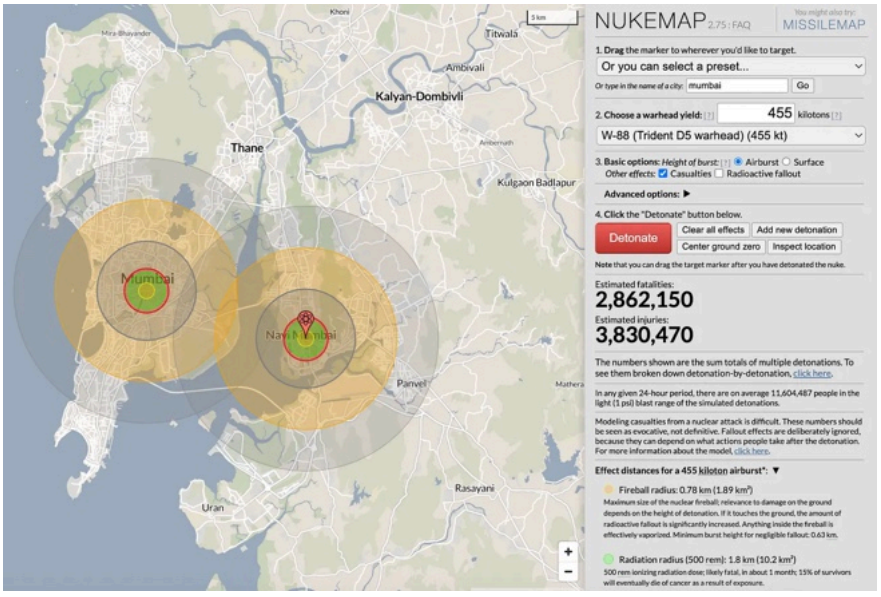
City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Megaton
Mumbai	20,7	60,3	39,7	71,1	14,72	5,98	64,18

Créé avec Datawrapper

The required explosive power is more than the Tsar Bomba explosion in 1961 with a yield of 50-58 megaton. Here are the results with NUKEMAP. Of course, this kind of weapon doesn’t exist in our arsenal.



What could be done using MIRV is targeting the city with two 455 kilotons weapons for example. Here are the results of this experiment :



While improving the area covered with these two bombs, the fact remains that smaller weapons even in large numbers are not guaranteed to reach the expected level of destruction. Or what will be required is to add more weapons leading to several bombs overlapping; which is far from being optimal.

Conclusion

We have done what military planners do every day under the pretence of "MAD" : the systematic and perfectly planned annihilation of entire cities using formulas and solving optimization problems

"Nuclear death math"

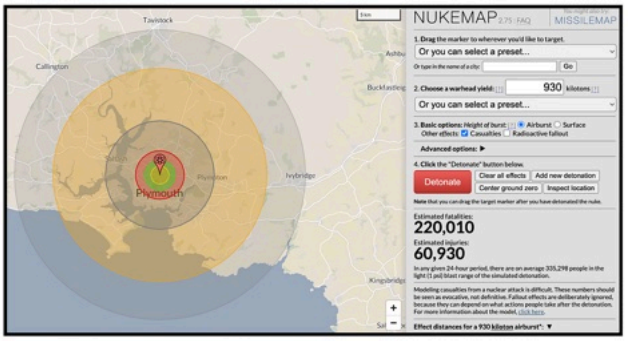
The formula for casualties can be described as this :

- Casualties = ((C × DC) + (M× DM)) / 100
- Let C be the percentage of population in the core area
- Let M be the percentage of population in the metropolitan area (where C + M = 100%)
- Let DC = 85 be the death rate for core areas
- Let DM = 50 be the death rate for metropolitan areas

The formula for megatons can be described as this :

- Megaton = (D / AD) × M
- Let D be the estimated deaths for a city
- Let AD be the average deaths per bomb (either 344,000 or 500,000 in our case)
- Let M be the average megaton value per bomb (1.5 MT)

City	Pop	Core %	Urban %	Rate	Deaths	Survivors	Low MT	High MT
Plymouth	0.26M	91.30%	87%	82%	0.21M	0.05M	0.64MT	0.93MT

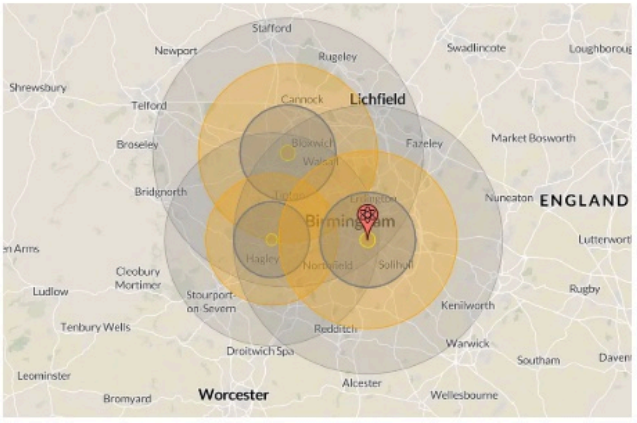


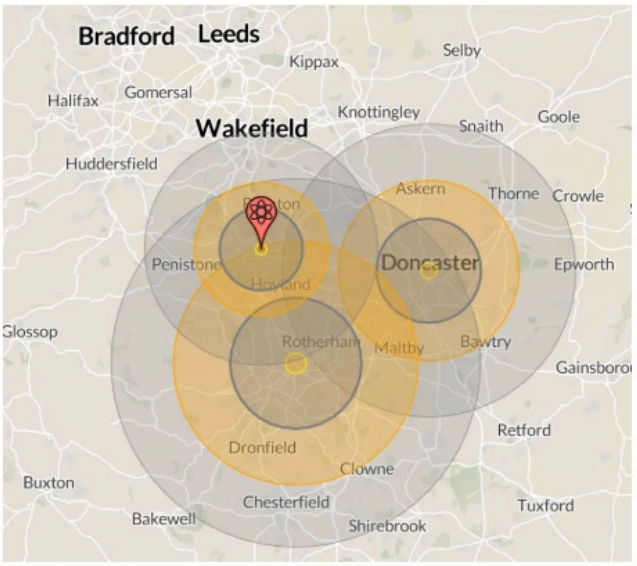
The way the whole topic is discussed is problematic because the key moral issue is avoided. That's not the bomb. That's what it means to plan their use. On this topic, the default "mode" of NUKEMAP is highly problematic. Especially for an educational tool. For the reader, the generated maps should be read as follows (from the center of every circle to the maximum extent :

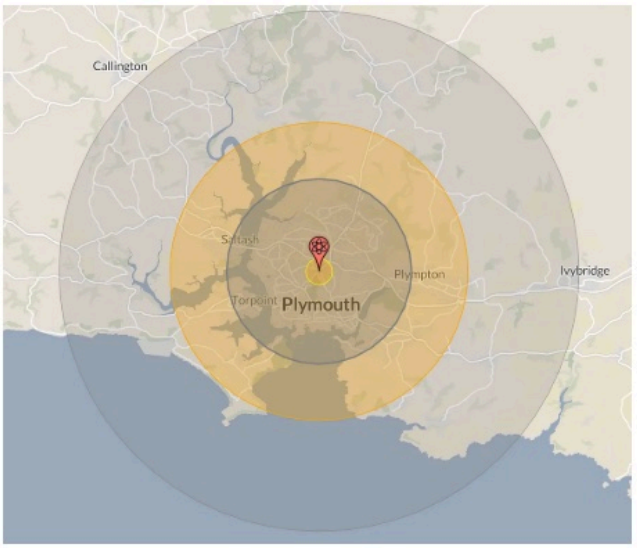
- The yellowish inner circle at the center of each detonation is the fireball
- The next grey circle ("dark" grey) is the medium damage blast radius extent

- The next orange circle is the extent of thermal radiation
- The last circle (“light” grey) show the maximum extent of light damage

Here is what my estimates look like over Birmingham, Sheffield and Plymouth :







NUKEMAP seems to compensate by including “injuries” in its estimates (still providing no explanation on calculations). Given what we see with these three maps using my estimations, my personal opinion is that “injuries” estimates are highly problematic given how massive is the coverage of each weapon (whether it is a conurbation or a small city) : fireball, moderate blast destruction radius, thermal radiation, light blast destruction radius… All these things (sometimes combined with overlapping effects in conurbations) can’t seriously lead to small and unrealistic estimates, especially in small cities where full coverage and even overkill is guaranteed. At this point, the survivability of this event for seriously injured people is extremely difficult (to say the least) given the potential destruction of all the infrastructures.

From my perspective, all the problems come from the 1973 report used by NUKEMAP as a basis for its methodology “The Effects of Nuclear War”. The sole maps available inside speak for themselves (either the very outdated “one bomb = one city” or unrealistic targeting models. Here is an example with Detroit from the paper :

Figure 12.—Leningrad Ten 40-kt Air Burst

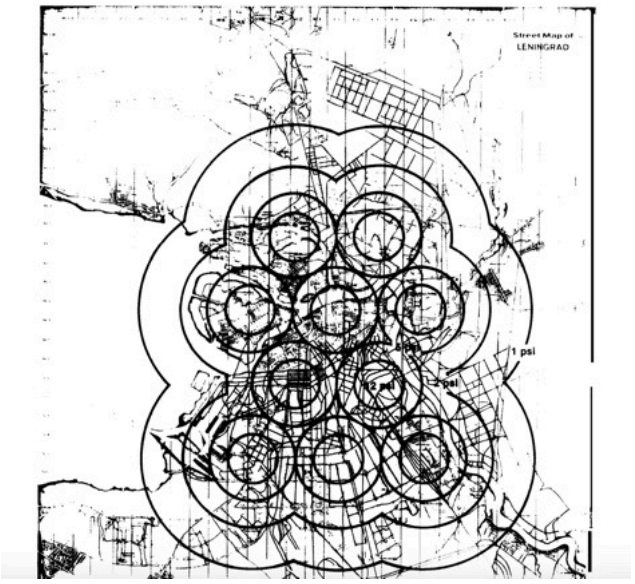
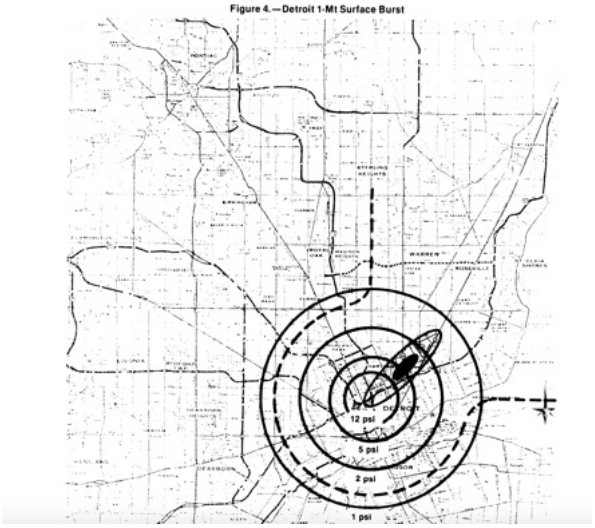
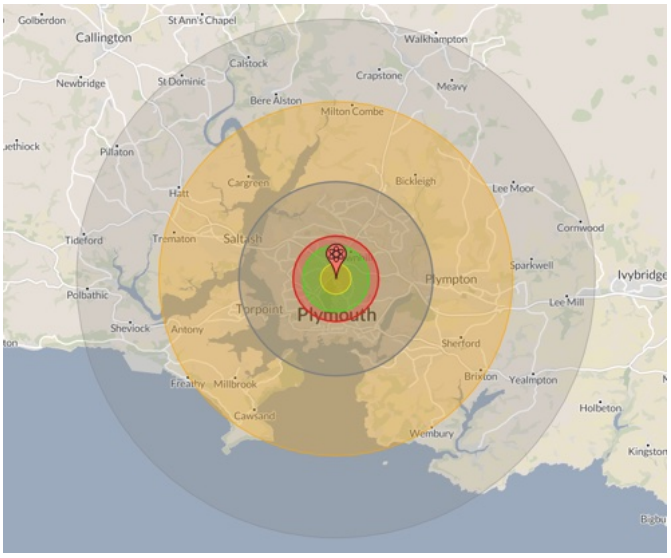


Figure 4.—Detroit 1-Mt Surface Burst



To be more honest about NUKEMAP danger and “apparent” limitations : the fact is that the simulator always defaults to the lowest estimate. Many people will probably never notice the “Advanced options”. When you open it, you will see that the software always defaults to the optimization of the “least” destructive radius : the medium destruction range. A lot of options are also defaulted to show the least damaging scenarios : like the height of bombing. From a military perspective, setting apart the destructive range we want to optimize, air bursts for nuclear weapons are generally done between 100 and 1000 meters above the ground. Let’s give a try with an 500 KT airburst over Plymouth like in my previous attempt, but this time at 1500 meters above the ground :



This time (when trying to do what military planners are going to do), the estimates for casualties are quite similar to my own estimates. You can also see the “heavy blast damage radius” in red; something the public will probably never see and understand. Even when you use historical nuclear weapons.

THE CONSEQUENCES OF A NUCLEAR WINTER — CASE STUDY ON THREE COUNTRIES IN THE 1980S

I decided to concentrate on the whereabouts of three of them : China, South Africa and Brazil. Especially, what could be the concrete consequences of the nuclear winter on agricultural production, and possible outcomes at regional level.

What is critical following a dramatic event like a nuclear winter, is how a country is able to organize cooperation at national level, prioritize and ration the food, while accounting for the inherent and unique local challenges.

I will account essentially for cereals because we have a crop failure rate from another similar event "Year without a summer" (1816). Cereals are also more "relatable" as it translates more easily as bread and flour, which form the core of our alimentation since millenia. It holds many advantages in terms of nutrition qualities during a famine : protein, fat, fiber, minerals like iron, zinc, magnesium… Historically, this is what is given (with soup) to starving people. For countries of the Southern Hemisphere, it translates as maize and rice too.

FAO guideline

The minimum intake value comes from the Food and Agriculture Organization of the United Nations, which is between the required 2000 calories for adults and 1000 calories for children. A midpoint of 1500 calories. It translates as 580 grams of bread per day or 1200 grams of cooked rice. Producing 580 grams of bread requires approximately 406 grams of flour (as a reference 453 grams of bread requires 269 grams of flour, or 60%). Producing 1200 grams of cooked rice requires 480 grams of "raw" rice ("One cup/Two and a half cups" rule, as rice cooking can vary with 1:2 and 1:3 rules). Of course, people rarely eat more than 250 grams of bread (150 grams of flour required depending on recipe, or 60%-70% of total) or 300 grams of cooked rice per day (120 grams of "raw" rice required, because "raw" rice nearly triple in size when cooked), but it illustrates what could be needed in absence of other sources of food to reach (at least) the needed calories per day. I also include maize which is a major staple food in the Southern Hemisphere. A daily intake of 250 grams of maize requires 100 grams of raw maize ("One cup/Two and a half cups" rule, similar to rice).

Historical famines lessons

The temptation could be to use the estimated death rate of similar famine (like the Great Irish Famine, which fits the context as being both natural and societal) and try to extrapolate it in our case. Unlike Hiroshima where deaths were caused by an explosion of a precise size (which allows a certain level of

extrapolation, if grounded in real-world constraints : density, finite stockpile, realistic targeting strategy, allocations problem…), the deaths of the Great Irish Famine have only to do with a lot of complex and intertwined reasons : crop failure, high dependency on a single source of food, undersized and inadequate relief scheme, specific Poor Law rules in 1840s Ireland…

Unfortunately, these factors are not replicable through the only use of data. They can't translate, like in my previous post on the consequences of a nuclear war on the UK, as a weighted average because it has nothing to do with urban or rural areas, or blast effect, for example.

Another fact is that many historical cases of major food shortages leave us baffled because no mass excess of deaths occurs, even below what is expected for them to occur (for example the Netherland famine in 1945 or Japan after capitulation), when the contrary happened during the Great Leap Forward or Bengal Famine. In dire situations like the Leningrad Blockade, deaths were widespread but diseases kept at bay. Theoretical resilience didn't equal practical results : under complete breakdown of front and logistics, the Soviet Union was largely able to feed its people during Operation Barbarossa. Expected social disruption didn't always occur as expected : Bengal saw no organized food riots on a large scale, contrary to what occurred on a regular basis before the famine. And when societies unravel beyond the scope of human comprehension, it's something that no data can even capture. For example during the Bengal famine : families disintegrated, child-selling occurred and people were exploited.

The famines are so complex that all attempts to capture a pattern to predict deaths can only fail. Let's take some examples and understand why you can't use them to predict how many people will die due to a nuclear winter famine :

- Leningrad Siege (900 days) : 1 million people out of a pre-war of 2.5 million (40%). Social cohesion was maintained at all cost. Can't be linked directly to crop failure, because the population was trapped within a besieged city
- Irish Famine (7 years) : 1 million people out of 8.5 million people before the famine in Ireland (11%). Major social upheavals. Linked to multiple factors : crop failure, Poor Laws and continuous exports… Because many people leave the country (nearly 3 million people), reconstructing a percentage is not guaranteed
- Bengal Famine (1 year) : nearly 4 million people. Many demographics figures of the time are unreliable to know the exact size of the Bengal population before the famine. Linked to multiple factors : crop failure, societal disintegration, war time policies…
- Great Leap Forward (4 years) : possibly 55 million people out of 647 million people (8%). Linked to multiple factors : poor economic policies, self reliance schemes, ban from leaving affected areas…
- Soviet famine in 1930s (1 year) : possibly 9 million people primarily in today Ukraine. Difficult to assess the pre-famine population because of the destruction of many census data. Linked primarily to the collectivization process in Soviet Union

For all these reasons, we should refrain from attempts to estimate deaths for a hypothetical famine. Focusing on food insecurity and trying to understand how a society can react to such stress provide far more insights than unreliable death estimates.

Many countries see a large part of their population suffering from chronic calories intake deficit (110 to 480 calories per day) without mass starvation. It leads indeed to stunted development, Kwashiorkor, scurvy, weakening of the immune system… but not to mass deaths. Famines are also never

spontaneous events and effects last several years in fact, even after food production resumes. Symptoms are progressive : weakness, weight loss, related-disease and inevitably death… even with resilience and coping systems. All these things lead to an excess of deaths over the years.

Methodology

For clarity, I decided to concentrate on food insecurity. To better assess the situation of each countries, the following figures will be given :

- What was available with pre-war harvest of cereals per day and per person compared with the consequences of the nuclear winter. Of course, it represents a perfect distribution between everyone, which is not necessarily going to happen for a lot of reasons (logistics, rationing, price…)
- How it compares to cooking different products, depending of course on what kind of crops a country is willing to prioritize. Sometimes you have some "excess" of food available (of course, it has nothing to do with pre-war surplus, it only means that sometimes a bit more cereals are marginally available), but it's important to understand of what we are speaking of : countries trying to feed equally everyone with a simple meal, from newborns to the elderly
- An amount as grams of fruits and vegetables which can complement what is available of cereals
- Livestock is not taken into account because its survivability is difficult (as for humans) to evaluate. In such a dire situation, the following is likely going to happen : a progressive shift toward herbivores who can survive with pastures (cattle, sheep, goats…) and the progressive disappearance of "monogastric animals" (pigs, poultry…) to reroute the available cereals to human consumption. As animals don't "fail" like crops, it's possible that in the first years we see the complete disappearance of poultry and pigs in many countries to compensate for crops failure

The main idea to estimate crop failure was to use a "gradient" approach. The worst case scenario is for northernmost countries with 75% of crop failure and minimum rate of 45% for the southernmost part of the world.

I used this fantastic paper to draw my hypothesis (Tambora and the "Year without summer" by Bern University, which I praise for several reasons : historical depth, societal analysis, climatic modeling while acknowledging that a climatic model can't predict everything, clear understanding that famine is complex result of intertwined factors). So what we know is that :

- The rain fall were severe across Central Europe
- Prices surge and food riots were common (but not universal)
- In France violence during the crisis reach the levels of "The Great Fear" famine
- Major political effects in the United States and migration to the West
- Effects weren't uniform across continental areas : droughts in Russia, rainfall in Central Europe
- In some places, people resorted to eat horses, something you see in war time countries when food is extremely scarce
- Effects lasted several years with shift in affected regions within countries
- The extreme value of 90% of crop failure is recorded for New England during the "Year without summer"

- Possibly 100 000 deaths worldwide

All these clues point toward something like 30–60 percent of crop failure with huge regional variations (perhaps less, perhaps more). Hence the bound of 45%–75% in my scenario.

The logic is that most of the nuclear exchange occurred between the East and the West. It's logical for the Northern Hemisphere to be the most impacted by this event. But clouds don't move according to borders, so the idea was to take into account that less light will be available too for the Southern Hemisphere, with a progressive decrease. It's a bit of a worst-case scenario, with an average of 75% crop failure in the Northern Hemisphere, and an average of 60% in the Southern Hemisphere to account for the natural diminished effect as the clouds "move" to the southernmost part. According to the "Year without summer" data, the crop failure can even reach 90% in the northernmost part (like New-England), even if it's not an upper bound here. Also important to note that the levels of crop failure are never uniform across such large areas, as are the clouds. But let's keep things simple. It applies as follow :

- 20°-Above 40° N (65%-75%) : Northern China and mainland China
- 0°–20° N (55%–65%) : Southern China
- 20°–0° S (45%–55%) : Brazil
- Below 20° S (45%) : South Africa

The framework, as simple as it is, avoids the mistake of using the same scale crop failure rate in every country. The fact is that climatic phenomena are never linear, so it was important to find a way to capture it. The framework uses basic reasoning and common sense : soot is more concentrated where nuclear bombs explode and dilute when the "clouds" move to the southern hemisphere. But due to the scale of the nuclear exchange, it was always also important to account for the idea that the impact was global. Hence the bound of 75% for the northernmost part and 45% for the southernmost part. 75% is in fact based on the "*faisceau d'indices*" method. I used this fantastic paper to draw my hypothesis (Tambora and the "Year without summer" by Bern University, which I praise for several reasons : historical depth, societal analysis, climatic modeling while acknowledging that a climatic model can't predict everything). So what we know is that :

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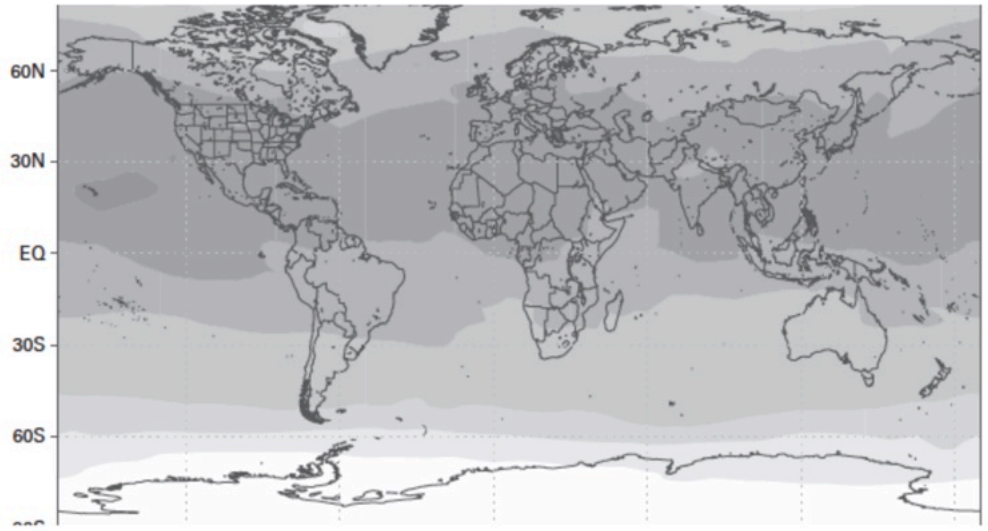
- Possibly 100 000 deaths worldwide

All these clues point toward something like 30–60 percent of crop failure with huge regional variations (perhaps less, perhaps more). Hence the bound of 45%–75% in my scenario. Something described by nuclear war studies on nuclear winter. An example :



Global smoke distribution from a 100-warhead nuclear exchange between India and Pakistan one month after the event. Darker shading indicates greater sunlight absorption. This map assumes that 5 million tons of soot was injected into the air, almost the same mass as the Great Pyramid of Giza.

China

Key figures in 1983 :

- Population: 1.03 billion
- International trade: Limited to non-existent
- Foreign aid: None, focus on self-reliance
- Food: Largely self-sufficient in cereal production
- Annual cereal production: 300 million tons
- Annual fruit production : 18 million tons
- Annual vegetable production : 68 million tons
- Oil production : 2.1–2.5 million barrels/day
- Oil consumption : 1.5–1.8 million barrels/day
- Net exporter of oil
- Industrial goods: Limited domestic manufacturing, significant import dependency
- Emerging from economic isolation, beginning to develop industrial capacity

It's unlikely that China was involved during the nuclear exchange, as the country was split from the Soviet Union in 1961, and was barely normalizing its relationship with the Soviet Union in early 80s. In the early 80s the Chinese began a slow economic reform process.

Following the nuclear exchange, it's not unlikely that China provided some food assistance to the Soviet Union. Despite being ideological enemies, a sense of solidarity could have emerged. But China is not going to immediately send its help. The Chinese leadership will in fact wait for the Soviet Union to ask for help. Something that is rooted in the fact that the Soviet Union had a history of never asking for external aid. But due to the scale of destruction in all the Northern Hemisphere, it will prove probably largely insufficient if the Soviet Union had the same societal collapse as the UK experienced following the war. With most of the destruction concentrated in Western Russia and

Central Asia, the Soviet Union will become a shadow of its former self. At a point or another, assisting the Soviet Union will prove impossible to pursue for the Chinese leadership.

Due to the global nuclear winter, China will face a harvest failure but two things will ponder : large size of arable lands (13%) and highly centralized food distribution system. It will be a difficult period, but not impossible, as the country has sizable agricultural lands and has a high level of control over food production and distribution. Nonetheless, the last point could be “double edged” because this crisis with no known precedent requires a high level of flexibility, something that is not guaranteed in this context.

The starvation is more likely going to be high to severe, with localized food unrest in the countryside and some major coastal cities. Chinese leadership will likely accept to “cut in half” the country to concentrate resources on coastal cities and immediate agricultural regions. Of course, take this “line” concept for what it is : an image. Reality will be more complex, as it always is, but due to the life-threatening and existential risks induced by the nuclear winter, choices are inevitable to know where to concentrate efforts. With 70% of the harvest lost, no international trades and no international aid, authorities in many countries are going to handle the situation as best as they can. At the beginning, the idea of this line is more to know where to allocate food : you allocate more food where most of your population lives. If the crisis continues, which is likely to happen in our context, some choices are inevitably going to be made regarding less strategic and populated areas.

With a major failure of the harvest (65–75% of the pre-war level, with a midpoint of 70%), China still has 90 millions tons of cereals (out of 300 million tons). As a comparison :

- 300 million tons translates to 291 kilograms of cereals per year and per person, or 798 grams per day and per person
- 90 million tons translates to 87 kilograms of cereals per year and per person, or 239 grams per day and per person
- It’s important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 131 grams per day and per person

This amount is insufficient for producing minimal levels of bread, but allow for a small excess in rice and maize (150 grams for bread, 120 grams for rice or 100 grams for maize) :

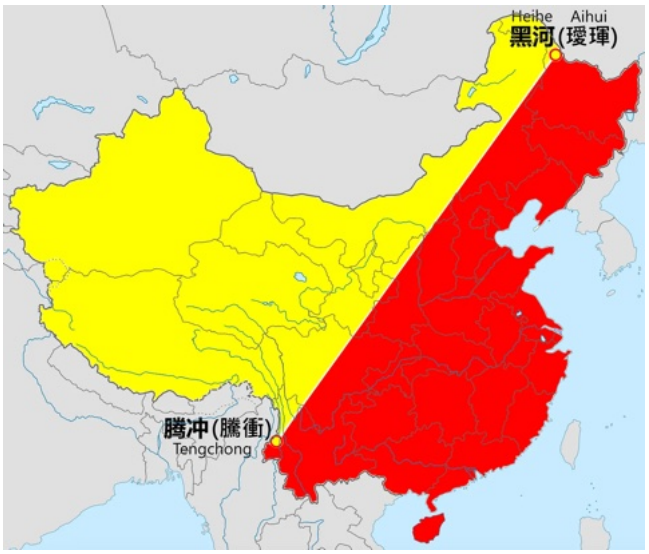
- It’s 87% of what is needed to cook 250 grams of bread (700 calories)
- It’s 109% of what is needed to cook 300 grams of rice (400 calories)
- It’s 131% of what is needed to cook 250 grams of maize (200 calories)

With 65–75% of crop failure (midpoint of 70%), only 5 million tons of fruits and 20 million tons of vegetables remain (out of 18 and 68 million tons). It translates as : 13 grams of fruits and 54 grams of vegetables per day and per person.

Regarding the oil consumption, China was a major and net producer, so the country won’t be impacted by fuel shortage.

To illustrate the point, here is a map of China with recent population data and how the line could be drawn (the approximate line is called “ Heihe–Tengchong Line”, at the east lies 94% of the population, the line can also be used to account for high levels of contamination following the nuclear

strikes in key Central Asia cities, which were part of the Soviet Union, and spill-over on Mongolia, more a satellite country of the Soviet Union at the time) :



Original source for the map :
https://commons.wikimedia.org/wiki/File:Heihe-tengchong-line.svg?uselang=en#Licensing

Something that aligns with the reality of the three main cereals cultivated in China (corn, rice and wheat; noting that corn were far less important in the 1980s than today) :

Within the years following the total destruction of Europe and the Soviet Union, China will inevitably consolidate its leadership in what is now a very diminished and hyper-localized region with the disappearance of the Northern Hemisphere and both superpowers.

It will mean a lot for South Korea, Taiwan and Japan who were dependent on the United States to provide them military assistance. The invasion of South Korea by the North or the annexation of Taiwan by China are highly implausible scenarios due to the nuclear winter severely impacting the harvest. Like everywhere, the only thing that matters is collecting a seriously diminished harvest and surviving without the international trades route. But the collapse of the Northern Hemisphere countries will be a “game changer” in local geopolitical realities. Facing the loss of the United States, South Korea, Taiwan and Japan will have to adapt and make some concessions; as China will have to due to the nuclear winter consequences and the disappearance of the Soviet Union. In fact, it leaves the room open for more cooperation, realism and pragmatism in absence of other viable options in face of such a catastrophic event.

There is no reason for the Chinese leadership to halt its economic reform. The harvest failure will inevitably push for even more reforms and innovation. But because the growth of China was fueled by its ability to become a manufacturing center for outsourcing countries, the growth will be more moderate with the annihilation of international trade. Also its ability to get machinery and knowledge to improve its industrial basis will prove problematic. And because China was (and still is) an oil producer, the self-reliance scheme will continue.

For China, putting aside the relative "ideological" triumph and regional role, the following years won't see the country becoming a major superpower and industrial hub.

South Africa

Key figures in 1983 :

- Population: 31 million
- International trade: Mostly high-value minerals, but constrained by international sanctions
- Foreign aid: None
- Food: High agricultural self-sufficiency due to advanced farming sector
- Annual cereal production: 6 million tons
- Annual fruit production : 3 million tons
- Annual vegetable production : 1.5 million tons
- Oil production : None to negligible
- Oil consumption : 0.4–0.5 million barrels/day
- Heavy importer of oil
- Industrial goods: Moderate self-reliance, developed manufacturing base
- Import restrictions due to international sanctions

Even as an "unofficial" ally of NATO and the United States, South Africa won't be impacted so much by the war, as South Africa was far away from the main theater of operations. The country was also deeply entangled by the internal protests and the Border War.

Following the nuclear exchange, the country will be more isolated than ever. Even with a lot of resources (food, minerals…), the country is far away from its allies. We can imagine a small number of boats dispatched to assist or contact the United States, but it will prove marginal. Like China, South Africa will suffer from harvest failure. Two things will ponder : the size of arable lands (but highly variable across the country : 10% main South Africa, but only 1% for South West Africa) and the high level of efficiency of South Africa agriculture.

The starvation is going to reach different levels across the country : high (main South Africa), severe (Bantustans, which were territories created to reallocate black population and totally subsidized by South Africa) and extremely severe (South West Africa, today Namibia). The harvest failure is going to hit South Africa in a multifaceted way : Border War operations are going to be halted in South West Africa due to the lack of fuel, the government will likely be unable to subsidize the Bantustans, the size of the country will push for relocation of people and resources, fuel rationing is going to be severe…

With a major failure of the harvest (45% crop failure rate), it means that only 3.3 million tons remain (out of 6 million tons). As a comparison :

- 6 million tons translates as 193 kilograms per year and per person, or 530 grams per day and per person
- 3.3 million tons translates as 106 kilograms per year and per person, or 291 grams per day and per person
- It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 160 grams per day and per person

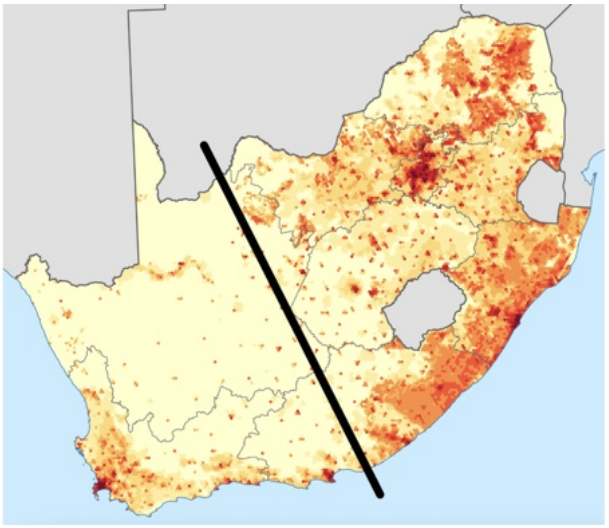
This amount allow for excesses in bread, rice and maize (150 grams for bread, 120 grams for rice or 100 grams for maize) :

- It's 106% of what is needed to cook 250 grams of bread (700 calories)
- It's 133% of what is needed to cook 300 grams of rice (400 calories)
- It's 160% of what was needed to cook 250 grams of maize (200 calories)

With a 45% crop failure, it means that only 1.6 million tons of fruits and 0.8 million tons of vegetables remain (out of 3 and 1.5 million tons) or : 141 grams of fruits and 70 grams of vegetables per day and per person.

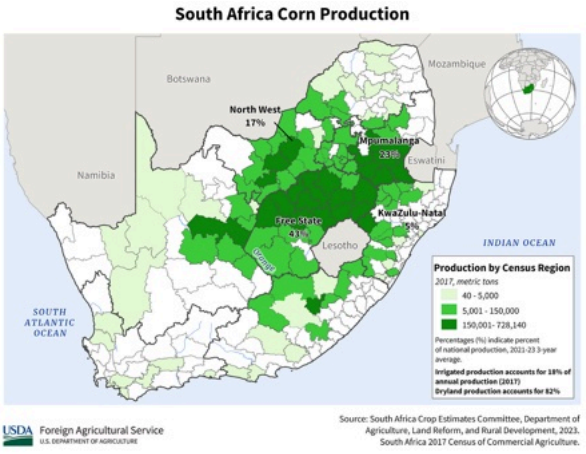
South Africa was not a major oil producer, and the collapse of international trade will completely hamper its capacity to manage the crisis. Hard choices are going to be made to know where to allocate fuel, even if some pre-war stock is available.

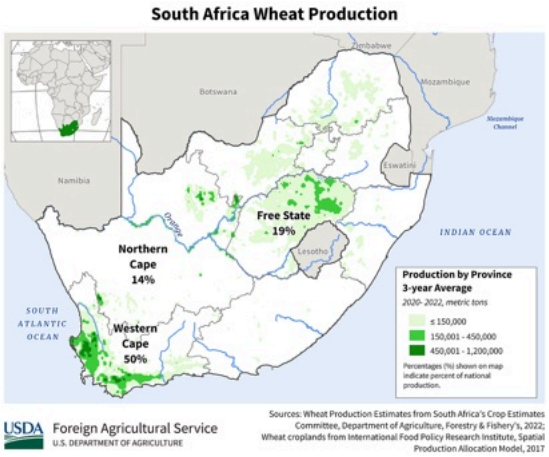
The most plausible mid and long term scenario during the first year is the complete withdrawal from South West Africa, abandonment of the Bantustan system and concentration on coastal and arable land areas in the east. To illustrate the point, here is a map of South Africa with modern density patterns, with a country cut in half, and clear focus on the most populated areas and arable lands in the east. This line is also important for a less optimistic scenario : the total collapse of urban and political areas in the east. East of line lies something like 80% of the population, and 20% lies on the west :



Orignal source for the map :
https://fr.m.wikipedia.org/wiki/Fichier:South_Africa_2011_population_density_map.svg

Something that aligns with maize cultivation areas (main cereal crop in South Africa) but less with wheat :





The nuclear exchange will be a real “game changer” for South Africa. The country was already isolated, but at least South Africa had some unofficial support before the war. After the war, it will have none. The country faced massive protests inside against apartheid and was involved in a costly war in South West Namibia (now Namibia). The only thing that saved the country in the 1980s from collapse was its ability to still export high-value minerals (gold, diamonds…). But with fewer or negligible countries to commerce with after the war, and because what will matter is food, it will prove difficult.

But the country was very resilient, as was its ability to sustain a low-level war from 1960 to 1990 with no assistance and facing numerically superior enemies, while still maintaining order in mainland South Africa. A comprehensive “import substitution” scheme was in place for both civilian and military products. The following years can see some improvement if the country is able to “pivot”.

The Border War will in fact cease by itself as most of the guerillas were supplied by Cuba, which in turn was assisted by the Soviet Union. The domino effect will render the Cuban operations impossible. The conflict was already a low-level war in fact, and skirmishes will become even more sporadic. And because of fuel constraints, South West Africa will likely be abandoned by the end of the year due to the impossibility to sustain the logistical burden of the war (to give a clear picture, the distance between South Africa-Namibia border and Namibia-Angola border is like 1200 kilometers).

But the “inner-front” is still there, fostered by the isolation of South Africa. Under extreme international isolation and internal unrest, South Africa can be compelled to revise its policies as a practical measure, even if it’s not as far as what was done in 1994. Like with China and surrounding countries : pragmatism and realism will prevail during such a catastrophic event.

The next major issue for South Africa in the following years, will be the need to manage a growing number of refugees from other parts of Africa. With the disappearance of the Northern Hemisphere, the international aid is going to disappear too. Zimbabwe (ex-Rhodesia) will be less hit due to its ability to produce a lot of food. But Mozambique and Botswana are going to be seriously hit by the nuclear winter. Africa was already a troubled continent, and the lack of foreign assistance will foster the crisis.

A difficult period for South Africa with harsh and realistic choices to make and the unavoidable loss of more than two thirds of its pre-war territorial area (if we include South West Africa).

Brazil

Key figures in 1983 :

- Population: 135 million
- International trade: Diversified exports, significant agricultural sector
- Foreign aid: Mixed status, receiving some development assistance while emerging as a regional economic power
- Food: Substantial agricultural self-sufficiency
- Annual cereal production: 30 million tons
- Annual fruits production : 18 million tons
- Annual vegetables production : 4 million tons
- Oil production: 0.2–0.3 million barrels/day (not including ethanol)
- Oil consumption: 1–1.2 million barrels/day
- Moderate importer of oil
- Industrial goods: Growing domestic manufacturing, but still import-dependent
- Developing industrial policy to reduce external technological dependence

Unlikely too is the involvement of Brazil in the nuclear exchange. Brazil was also a regime engaged in an unstoppable democratization process, with a strong emphasis on national development. Several historical factors are at play. It's important to note the country was seriously hit by the fuel crisis in the late 1970s and borrowed billions of dollars to go through. As a result, the country had slowly started to shift from unilateral alignment with the United States to a more pragmatic foreign policy. Like China and South Africa, it was a growing major regional country.

Because of its ties with the United States, Brazil will probably do the same things as South Africa : sending for a moment some negligible assistance in a contaminated and desolate wasteland beyond recovery. Like China and South Africa, the country will suffer a harvest failure. Despite the impressive agricultural output, the country has very small arable lands (6–7%). The starvation is going to be high to severe, with the abandonment of many projects like the land clearance in Amazonia.

With a major failure of the harvest (45%-55% of crop rate failure, with a midpoint of 50%), it means that only 15 million tons remain (out of 30 million tons). As a comparison :

- 30 million tons translates as 222 kilograms per year and per person, or 608 grams per day and per person
- 15 million tons translates as 111 kilograms per year and per person, or 304 grams per day and per person
- It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 167 grams per day and per person

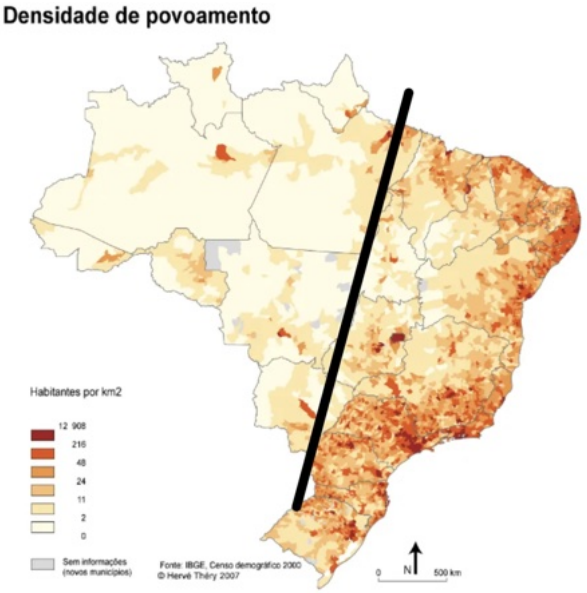
This amount allow moderate excesses for producing minimal levels of breads, rice and maize (150 grams for bread, 120 grams for rice or 100 grams of maize) :

- It's 111% of what is needed to cook 250 grams of bread (700 calories)
- It's 139% of what is needed to cook 300 grams of rice (400 calories)
- It's 167% of what is needed to cook 250 grams of maize (200 calories)

With a 50% crop failure rate, it means that only 9 million tons of fruit and 2 million tons of vegetables remain (out of 18 and 4 million tons) : 183 grams of fruits and 41 grams of vegetables per day and per person.

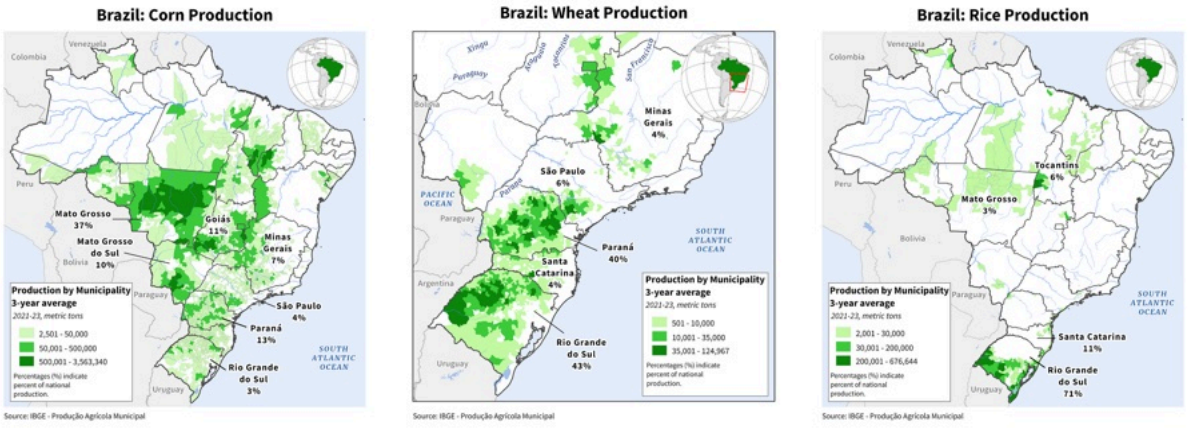
With only 20% of its fuel consumption covered by local production, a rationing scheme is necessarily going to be organized, even if the conditions are better than in South Africa.

Most of the difficulties are going to be concentrated in and around the Sao-Paulo and Rio de Janeiro regions, which are highly urbanized, dependent on other regions for food and with few possibilities to even shift on subsistence farming. Here is a map to illustrate the possible abandonment of Amazonian regions and shift to coastal areas (something like 85% of the population east of the line, 15 % on the west side) :



Original source for the map :
https://fr.m.wikipedia.org/wiki/Fichier:ARCHELLA_E_THERY_Img_05.png

Something not perfectly aligned with corn cultivation areas (main cereal crops in Brazil) but well aligned with rice and wheat :



Economically, Brazil will struggle at the beginning because of industrial goods imports and the disappearance of all the economic aid. The process of “import substitution” will be difficult. But

Brazil has two major assets. The first was the launch in 1975 of the “ProAlcool” program to replace oil by ethanol. It could prove invaluable inside and outside. The second asset is the great expertise of Brazil in agriculture with nearly every product, which can prove invaluable to adapt to the nuclear winter.

The real “unknown” is how the different countries in its neighborhood will interact with each other. Small crises like those regarding the Soviet-Sino border can occur, for example over the Amazonian region. But due to the immediate consequences of the nuclear winter and the collapse of the Amazonian region due to the inability to travel long distances, it’s more likely for surrounding countries to focus exclusively on agricultural production than on meaningless border disputes.

For Brazil, the nuclear exchange will most likely temporarily halt the ongoing process of transformation into a major regional power (and if it occurs, it will be a “de facto” result), with the loss of control over more than half of the country.

Rationing system

While we have discussed how much cereals could be available, we have not discussed how to distribute the food equally between everyone. I don’t expect the blocking of sun rays to last more than one year, so at a point or another, harvests will progressively reach pre-war levels. To imagine how rationing could work, I will use the worst-case scenario : China with only 131 grams of cereals per person and per day (after accounting for seeds, livestock consumption and storage), 13 grams of fruits and 54 grams of vegetables. It’s important to note that pre-war stock, dairy and meat products were not included in previous calculations of available food; even if it’s impossible that the stock, dairy and meat suddenly disappeared with the nuclear winter. Note that the following amounts of food are theoretical and don’t account for agricultural products cycles.

Because we need to translate cereals in a cooked form, and because China mainly consumes rice, what we want to reach is a certain value of cooked rice (with a 2.5 ratio between raw and cooked rice). It means that theoretically everyone can get 300 grams of cooked rice per day (120 grams of raw rice, or 400 calories). In 1980s China the average household size was 4 people, which means 1200 grams of cooked rice for 4 people. Normally this amount should be more toward 900 or 1000 grams per day of cooked rice or six servings of 160 grams each.

The initial stock before seeds, animal consumption and storage was 90 million tons of cereals. With 45% for this task, 55% remain for human consumption or 49 million tons. What we need is to find a nice balance between the need to care for the youngest and allow workers to work without being too exhausted, while not abandoning the elderly. Even it proves insufficient. History shows us that when we abandon the weakest, societies inevitably unravel beyond recognition. This “equitable” distribution is a bit optimistic when we know from history that in dire situations, we unfortunately tend to abandon the weakest. It works as follow :

- The very young will receive 240 grams of cooked rice per day. Or 96 grams of raw rice. It could possibly represent 10% of the population in 1983, or 103 million people. It represents 3 609 120 000 000 grams a year, or 3.6 million tons of cereals
- The very old accounted perhaps for something like 5% of the population, or 52 million people. Their ration is fixed at 240 grams of cooked rice per day. Or 96 grams of raw rice per day. It translates as 1 822 080 000 000 grams per year, or 1.8 million tons of cereals

- What remains of the population (875 million people) will get what remains of the cereals, or 43.6 million tons of cereals. It represents 43 600 000 000 000 grams. It represents 49 kilograms per person and per year. It represents 134 grams of raw rice per day, or 335 grams of cooked rice per day.

Fruits could be given to everyone, but past cases show that fruits are generally given to children to compensate for lack of food and because they are growing. In 1983, the children between 0 and 9 years old represented something like 21% of the Chinese population (or 216 million people). 5 million tons of fruits are still available. It represents 5 000 000 000 000 grams, and it translates as 23 kilograms per year, and 63 grams per day and per child.

Vegetables can be given to everyone to compensate for the lack of other food and ensure some diversity in food intake, even if it represents only 54 grams per person and per day.

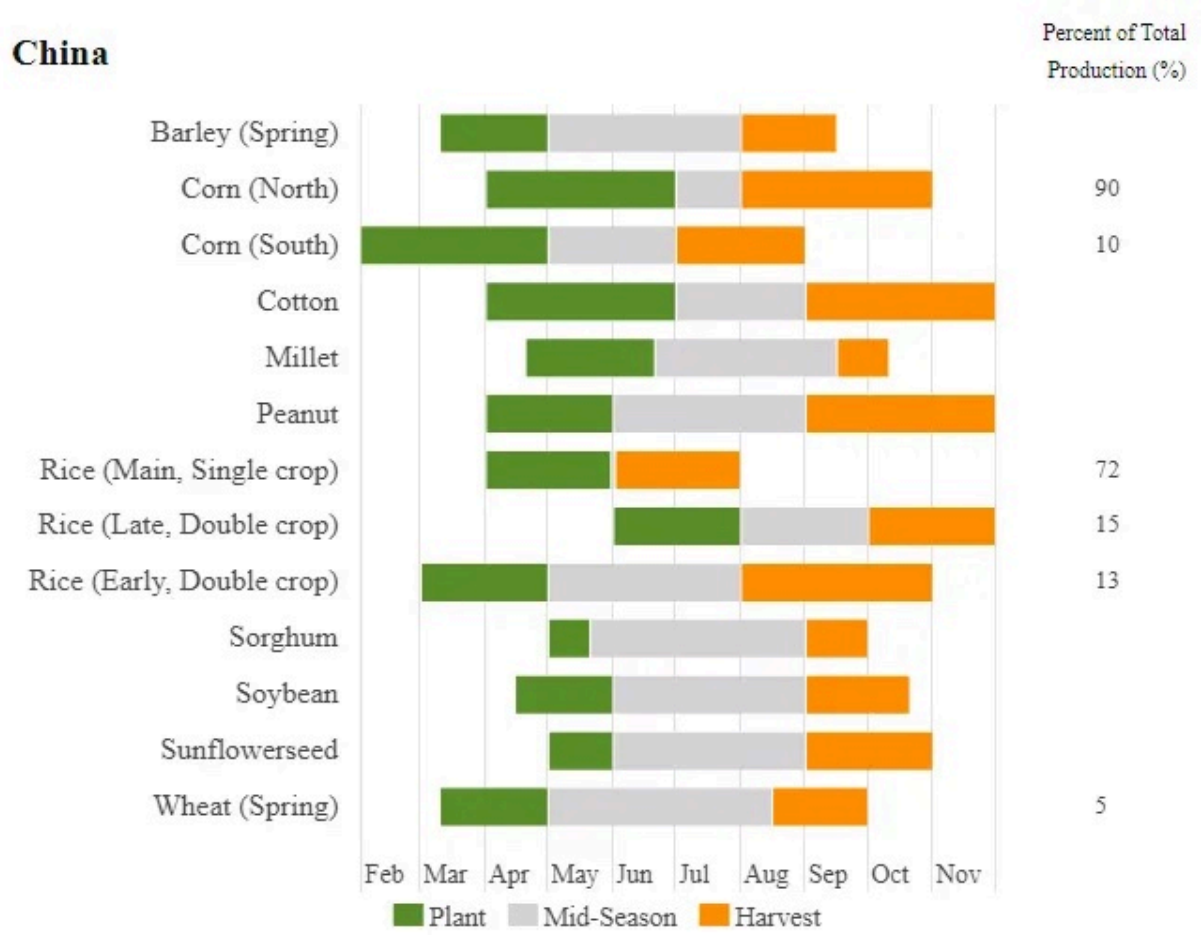
Regarding meat consumption, I said earlier that animals don't "fail" like crops. I didn't account for them, but there is no reason for animals to suddenly disappear from China during the nuclear winter. As a basis, China consumed something like 13 million tons of meat in 1983. Applying the same failure rate as for crops would be a total nonsense, as meat consumption is probably going to increase. It will represent 13 000 000 000 000 grams of meat. Divided by the whole population, it means that everyone can get 12 kilograms per year, or 33 grams of meat everyday. This is more likely to come as something like 231 grams of meat every week.

What could be done to avoid the worst ?

Most nuclear winter studies discuss countries in the Southern Hemisphere. Countries normally not likely to be involved in a nuclear exchange. Discussing solutions for these countries is perfectly logical : these people hold no responsibilities in what could occur to them. Something that is not limited to a hypothetical nuclear winter, but also more broadly to the topic of food security. And unfortunately, nuclear weapons exist. Rather than indulging in "doomsday fantasies", we should discuss the risk. Especially for countries indirectly affected. The fact remains that a severe agricultural disruption can be caused by many things : political instability, civil wars, sea level rising, major pandemic…

The first logical thing for many countries is to always store foodstuff (whether it's cereals, canned/frozen food…). In our Chinese case, let's say we have stored 10% of the previous harvest before the nuclear winter (circa the same amount) or 30 000 000. Something extremely modest, but a possible improvement of nearly 100 grams of raw cereals per day and per person.

What could "lighten" the previous discussion is that agricultural systems are cycles by nature. Here is an example of the modern Chinese agricultural system calendar :



USDA Foreign Agricultural Service

Even if difficult, the fact that several products could be harvested over the course of a year can contribute to soften the burden for the country, if the harvest is not too compromised and if the effects of the nuclear winter are not lasting too long. That's why social cohesion, even if it is difficult to maintain with rationing, is important because people and the agricultural system need to bounce back. Something you can't do in a divided society. On an agricultural topic, what could be interesting too is to develop alternatives to sole cereals; especially root/tuber crops known for their interesting yields. They could face nuclear winter effects too, but given their natural high yields, it could be nice products to integrate in current agricultural frameworks to provide food—even if this is limited to bounce back. What matters too is the ability for countries to maintain seeds banks/stock. In a context of a major agricultural and food crisis, being able to mobilize people around food production—even if it could be naive—seems important for us : we are going to produce food in a country lacking it, a project that could easily mobilize people. Whether it is in the form of large agricultural projects or even simple communal gardens.

Concerning us is the development of young children. Because they are not expected to work, they could have "diminished" ration (again, something that has nothing to do with the worth of an individual, but with the fact that working people need more energy). Prioritizing them for fruits is important but not necessarily sufficient. What should be important for countries is to store emergency vitamin "mix". This is not a perfect solution (not better than eating fruits of course) but something that should matter given the risk for young children to face stunted development and sickness at early ages. What matters too for them is the ability to maintain a strong health service to care for the most

vulnerable : young and old people. Something that concerns the social fabric too : the more the burden is shared, the more we are able to build a common narrative, the less the society is susceptible to face severe shocks.

Regarding the possibility of a nuclear war outbreak, that's not something going to happen suddenly. It will probably be the result of an escalating conflict. Basically, many countries are going to take measures to control and assess the level of many critical supplies if the threat is taken seriously : food, fuel, medication… Moreover, the escalation will likely lead to a surge in cereal price on the international market, leading many countries to enforce strict measures for price control and stock. This was the case for example during the COVID crisis, with many countries taking such actions and banning exports, especially for staple products : Bangladesh, China, Egypt, Vietnam, Russia… Measures could also be taken to control "panic buying" locally (before and during the nuclear winter). Something theoretical, but that matters too.

To conclude on the "true" severity of a nuclear winter, the fact remains that we don't know. The "Year without summer" despite its extreme severity in Europe and other parts of the world—in the context of post-Napoleonic wars for Europe—didn't result in total societal and agricultural collapse; neither in human extinction, despite less advanced agricultural technologies. We are concerned by how an hypothetical massive agricultural disruption is described : a near total extinction event. The fact remains that societies faced for centuries multiple agricultural disruptions, and even lasting crop failures. None of them resulted in total extinction of the affected countries or regions (like the Great Famine of 1315–1317 or Russian famine of 1601–1603, the latter possibly resulting in the death of nearly ⅓ of the population). The cases we have discussed earlier are extremes : massive crop failures rates on whole countries with no agricultural/crops temporality.

What we have discussed here is no "miracle" solution but common sense regarding food security : seeds, social cohesion, rationing, crop diversity, strategic stockpiling, food exports restriction, vitamins mix… The best we can do. Far more responsible than indulging in non-sense bodycount studies.

A COMPARATIVE STUDY ON MAINSTREAM NUCLEAR WAR MODELS — CASE STUDY WITH NUKEMAP, NWS AND LILI XIA ET AL. (2022)

When we look at many mainstream papers and models related to how a nuclear exchange unfolds and what happens next, we are quite surprised by the lack of nuance in their outcomes. The idea is not to merely criticize, but to understand why they didn't capture the complexity of the topic, and to be constructive regarding what could be done to improve the field of the nuclear war studies; to produce more nuanced and useful models.

On how nuclear weapons work and how a nuclear exchange unfolds

In my previous entry now available on Medium "The consequences of a nuclear war : case study on 80s UK", I explained how a nuclear exchange could have unfolded over the UK. Inevitably, the question of "How we evaluate the number of dead " arises. I was clear at the very beginning on the fact that you can't use the megatonnage value of a bomb to estimate how many died :

"*In Hiroshima, the death estimates are as low as 90 000 and as high as 166 000, out of a population of 255 000 people. Or 35% to 65% of the population. But we must be careful with such figures, as it's not possible to scale the power of the bomb used at Hiroshima with the modern rates of megaton. Because you cannot scale a death rate of 9300 deaths per kiloton (the Little Boy was 15 KT) to 126 Megaton. It would mean that 126 megatons kills 1 billion people. Because even if we use such a big weapon over a single area, the maximum will still be how many people live there. An increase in blast radius does not necessarily cause scaling of deaths with the same ratio*."

The statement is clear : megatons can't be part of the equation because the only thing we can do is scale if we use it. What was done in my paper was the following :

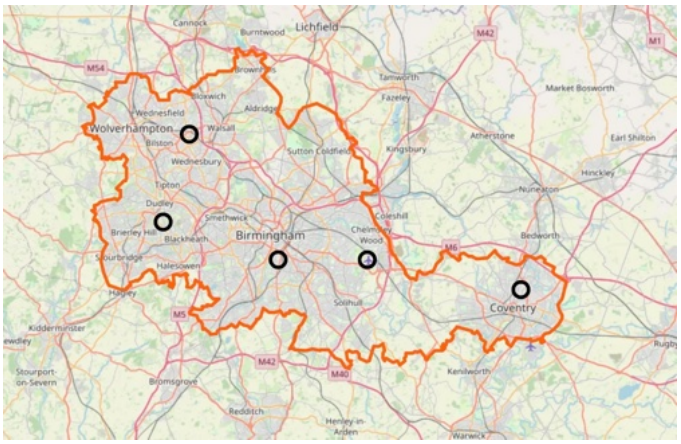
- Because I accounted for the idea that targeting is decentralized especially in large conurbations, I make sure to split all major urban centers and cities in two things : core and metropolitan area
- I use the lowest and highest death rates at Hiroshima and "update" them with an increment of 15% to account for the increase of destructive capability
- I split the death rate between core and metropolitan area
- To estimate how many people died in the areas, I used a weighted average

Why does it work ? As simple as it seems, the model avoided the issue of including too many variables which didn't guarantee better accuracy and made the underlying logic less understandable.

Perhaps I'm wrong regarding the deaths at Hiroshima. Some will argue that the pre-bombing population was higher/lower (something that in fact no one even is sure today), that some estimates include long term diseases (or not) and so on. The fact is that my conclusion came from my extensive research on Hiroshima : survivors testimonies, pictures made by photographers on the ground, injuries reports and pictures, scale of near total destruction with such a little bomb… Nothing points to an optimistic survival rate with bigger weapons (from small cities to large conurbations). The experience of the people who died (and survived) at Hiroshima, from my personal perspective, tells us that nuclear weapons have nothing to do with "curves" or nonsense formulae, but with something so powerful and destructive that no resilience or good will matter unfortunately.

The idea of splitting an urban center or a city between a "core" and "metro" area is useful because we account for how modern cities grow together. You can't build a serious model if you don't account for basic urban reality.

Because I accounted for the idea that bombs will fall both on the “core” and “metro” areas (because the area are sometimes so large and because many infrastructures are dispersed, that doing otherwise is not realistic), it was important to account for the possibility that people will die both in the “core” and both in the “metro”. This idea was illustrated by this map of the “West Midlands conurbation” with possible targets :



The area is so large that hitting only the center of Birmingham is not realistic. Multiple weapons are required to cripple this major urban and economic center.

Because a nuclear bombing is inherently a physical phenomena, what I did was what we call in French “*un faisceau d’indices*” (or literally “a bundle of clues”). Based on what we know from Hiroshima (pictures, census records…) and with our knowledge of what modern nuclear weapon can do (Hiroshima fireball was less than 400 meters in diameter, when a 1 megaton weapon is around 1 kilometer), it was logical to use the estimates of Hiroshima as “baseline” and update them a little bit.

Even if it’s not a perfect truth : core cities tend generally to be more dense while metro areas are more sprawled. So it was logical to have fewer deaths in large sprawled areas than in a denser one. The idea was also fitting several cases at once. Major metropolitan areas (like Greater Manchester) will suffer numerically more deaths, but proportionally less people in terms of percent of total population. While smaller cities (with nearly all the population in “core”) will suffer less numerically but more proportionally.

Finally, a weighted average was used for each city to assess its uniqueness thus breaking in some way the risk of applying a linear death rate across all the cities. It also introduces the idea that deaths are uneven across (and inside) all the cities because of their inherent differences, and because we need to account for uncertainties regarding targeting. Even if the death rate were updated from Hiroshima, we still account for the density and geography of every urban area with this simple method.

The formula can be described as this :

- Casualties = ((C × DC) + (M× DM)) / 100
- Let C be the percentage of population in the core area
- Let M be the percentage of population in the metropolitan area (where C + M = 100%)
- Let DC = 85 be the death rate for core areas
- Let DM = 50 be the death rate for metropolitan areas

Imagine Greater Manchester today. The total population is 2.9 million inhabitants. Manchester alone has 0.5 million people. Manchester accounts logically for 17% of the conurbations. The metropolitan area represents 83% of the conurbation population. Now we can apply the death rate with 85% for core and 50% for metro, and some kind of weighted average or : ((17 x 85) + (83 x 50)) / 100 = (1445 + 4150) / 100 = 55.9%. Because the people never live only in the core, nor only in the metropolitan area, the death rate is always between 50%–85%.

So what happens to many other models ? Despite knowing perfectly the fact that we can't scale from Hiroshima with the megatons, the same error is made. The most critical issue is that many mainstream models like NUKEMAP or NUCLEAR WAR SIMULATOR (NWS) don't capture the geographic reality of modern cities. It has nothing to do with using complex and proprietary databases to assess at every single inch the density of a city. What matters is our understanding on how cities grow together and how a nuclear exchange unfolds. My previous paper was clear on this point, we also need to deal with real-world constraints :

"*How the nuclear attack is conducted in Threads suggests that something like 30% (or 40 bombs) won't fall on cities because military targets are prioritized. With an average of 1.5 megaton per bomb, it represents 60 megaton. It's also important to account for the destruction of many strategic infrastructures like airports, cargo ports and nuclear power plants. In case of a full scale nuclear exchange in 80s UK, we can imagine the destruction of :*

- *10 cargo handling ports*
- *12 international or major airports*
- *10 nuclear and conventional power plants*
- *10 oil refineries*

It represents a total of 42 bombs used (or 30%), or 63 megatons. We now have 58 bombs (87 megatons) ready to fall on the biggest cities of the UK."

The assumption is clear : you can't cripple a country with the sole destruction of the population centers. If we add this to the need of destroying large urban areas, it's clear that we need to shift from the outdated "one city = one bomb" to the allocation problems I introduced later in my paper : we have few bombs and multiple cities to destroy. It means that we cannot think anymore in terms of individual cities but in terms of large conurbations. Mainstream models fail because they inevitably lead to overlapping, as they refuse to account for real-world constraints : finite stockpile, military strategy and urban reality.

Trying to calculate "individual" casualties on each city in a very tight-knit urban area while avoiding overlapping is highly inefficient in terms of computation : How to know who died because of what bomb ? The most logical option is to aggregate large urban areas if they are "sound" in geographic terms, and apply calculations within them.

Because they still rely on the old "one city = one bomb", they fail to understand the interconnectedness of modern urban areas. NUKEMAP is misleading in the sense that people think they "understand" the scale of a nuclear attack, but the fact is that it means nothing : the reality is far more horrifying in fact. NUCLEAR WAR SIMULATOR (NWS) falls short too as its methodology doesn't account for it. What is probably done by NUKEMAP and NUCLEAR WAR SIMULATOR behind the wall is the following : applying the very basic "one city = one bomb" within a large interconnected conurbation and sequential reconstructing of the deaths of every single strike.

Neither NUKEMAP, nor NUCLEAR WAR SIMULATOR, are able to produce any comprehensive explanations on how they estimated the deaths, how they account for modern urbanism, finite stockpile and for realistic targeting. NUKEMAP relies on proprietary databases :

"*The casualties model queries a very large and very fine-grained ambient population database known as the LandScan Global Population 2011. The database was developed by Oak Ridge National Laboratory and is licensed through a company called EastView. Special thanks to the Center for the History of Physics at the American Institute of Physics for purchasing this database for my use. "Ambient population" here means a 24-hour average of people in an area. In many respects this is better than census information, because that usually just measures where people live, as opposed to where they go when they are not at home.*"

So basically, we can't verify anything. My model is less "refined" but I was transparent on the fact I used mostly public census data. So basically, anyone can understand (because all tables are available with all the needed figures) how figures were derived. With NUKEMAP we don't know. NUCLEAR WAR SIMULATOR (NWS) relies on complex and "raw" databases :

"*Population density is imported from the GHSL Data Package 2019 https://ec.europa.eu/jrc/en/publication/ghsl-data-package-2019.*"

The data are possibly invaluable from a "machine learning" perspective. But because they are raw and still need to be aggregated to be useful, a pre-processing step is required. So, we still don't know what was really done (or not) on them.

NUKEMAP still relies on the only "blast radii" idea while still not being able to explain (and even assume) its results. The methodology of NUKEMAP speaks for itself :

"*The database spits back information about how many people live within several radii of ground zero. This information is then used to generate a list of casualties and injuries, according to data contained in a 1973 report by the Defense Civil Preparedness Agency titled DCPA Attack Environment Manual, later reprinted in the 1979 Office of Technology Assessment report, The Effects of Nuclear War.*

[…]

As you can see, it primarily relies on blast effects (pounds per square inch) as a proxy for calculating injuries and fatalities.There are limitations to this model.

For some yields, especially those which are very low or very high, blast effects are less important than thermal or radiation effects. The model itself also does not take into effect the fact that highly dense urban areas have a "shielding" effect from blast effects—those buildings nearest the ground zero bear most of the brunt of the blast. It's also not entirely clear what the OTA based these estimates on.

So the numbers might be too high. They also might be too low. Without taking into account many more variables than the model can deal with, like terrain type, building type, expected reaction of the bombed populace, and radioactive fallout, it's hard to do anything more than gesture at the numbers that would be affected by a nuclear explosion. I'm not trying to say "it's too complicated, so any model is as good as any other." But in choosing a model I went with one that could be relatively straightforwardly be implemented given the data I have available, and was backed by at least one

serious source. So I thoroughly encourage you to take these numbers with a grain of salt—they give some indication of how many people live in reasonably close proximity to the selected ground zero.

I have seen some other official estimates of fatalities and injuries that put the numbers (especially of the injured) much higher than the estimates that are given by the casualty model here, and I have seen some other official estimates of blast effects that would put it lower depending on the building types. It's not my intention to over- or under-exaggerate the effects."

The basic reasoning is that a model providing no clues on how results are derived is harmful, because basically nothing can be verified or understood. The most surprising thing is how NUKEMAP raises more issues than solutions on its very own model. This is like "My model used the best academic paper ever made, but I think that results don't really hold, so be cautious". Mine is not perfect, but because everything is transparent and clear, anyone can assess or update the needed parameters. Example of a table regarding major industrial and urban centers :

Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
Manchester	2,34	23,8	76,20	58,33	1,36	0,98	4,09	5,95
Birmingham	2,28	46,2	53,80	66,17	1,51	0,77	4,53	6,58
Liverpool	1,95	28,4	71,60	59,94	1,17	0,78	3,51	5,10
Glasgow	1,65	44,7	55,30	65,65	1,08	0,57	3,25	4,72
Leeds	1,48	51,2	48,80	67,92	1,01	0,47	3,02	4,38
Sheffield	1,24	45,6	54,40	65,96	0,82	0,42	2,45	3,57
Newcastle	1,14	35,8	64,20	62,53	0,71	0,43	2,14	3,11
Nottingham	0,73	45,1	54,90	65,79	0,48	0,25	1,44	2,09
Belfast	0,67	58,4	41,60	70,44	0,47	0,20	1,42	2,06
Coventry	0,65	53,8	46,20	68,83	0,45	0,20	1,34	1,95
Bradford	0,52	57,3	42,70	70,06	0,36	0,16	1,09	1,59
Portsmouth	0,48	42,6	57,40	64,91	0,31	0,17	0,93	1,36
Stoke-on-Trent	0,39	69,5	30,50	74,33	0,29	0,10	0,87	1,26
Cardiff	0,31	64,2	35,80	72,47	0,22	0,09	0,67	0,98
Plymouth	0,26	91,3	8,70	81,96	0,21	0,05	0,64	0,93

Created with Datawrapper

The megaton value per city is determined by using my estimate from a previous work (20 million people) and the Square Leg Exercise estimates (29 million people), it works as follows :

"*We now have 58 bombs (87 megatons) ready to fall on the biggest cities of the UK. With 20 million deaths, it gives us an average of 344 000 people killed by a bomb. With 29 million deaths, it's an*

average of 500 000 people. […] the lowest megaton was calculated by dividing the amount of deaths by 0.500 and by 0.344 for the highest, and multiply them by 1.5 to account for the average megaton of every bombs"

The formula can be described as this :

- Megaton = (D / AD) × M
- Let D be the estimated deaths for a city
- Let AD be the average deaths per bomb (either 344,000 or 500,000 in our case)
- Let M be the average megaton value per bomb (1.5 MT)

Like I said in my original post : "The idea of "optimizing" the destruction of cities could seem unsettling, but this is unfortunately what military planners do every day when they want to find the best way to optimize their weapons.". I can't be more clear : nuclear warfare strategy has nothing to do with being kind. Many of the people who will find the way I discuss the topic unacceptable from a moral and ethical perspective, are probably the same who are still justifying the destruction of Hiroshima (and the death and suffering of people on the ground) as an inevitable process to force Japan to capitulate. The same people who think of this event with a sense of detachment like if nothing was planned and studied before the bombing of Hiroshima. "Their inevitable" event was in fact carefully planned. Hiroshima was considered a strategic asset. The day of the bombing was chosen because the weather was perfect. Even the height of the detonation was perfectly calculated to maximize damages.

To show a working example, we can use the lowest megaton value estimates for Manchester and Plymouth :

- For Manchester, the estimate was 1.36 million deaths. It gives us : (1.36 / 0.5) * 1.5 = 2.72 * 1.5 = 4.08 MT
- For Plymouth, the estimate was 0.21 million deaths. It gives us : (0.21 / 0.5) * 1.5 = 0.42 * 1.5 = 0.63 MT

Basically, the estimate can be achieved by any ratio of people killed by a single bomb. You can use whatever you want. But my paper is clear : the megaton is deduced from the estimated destructive power of a single weapon, not the opposite. It has nothing to do with linearly scaling the effects of yields on cities and population, because the megaton value was never used to deduce the number of deaths. Instead, our idea is to understand what kind of weapon is required. Logically, a very small and concentrated city requires a smaller megaton value than a large conurbation. An improvement could consist in allocating nuclear weapons on a predetermined number of cities to calculate an average value of destructive weapons, and reconstruct the megaton value (given the average megaton value of each bomb). This table using the biggest and smallest cities (London and Londonderry) illustrates perfectly this issue :

Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
London	6,83	42,5	57,5	64,9	4,43	2,40	13,29	19,32
Londonderry	0,11	77,5	22,5	77,1	0,08	0,03	0,25	0,37

Created with Datawrapper

As you can see, more megatons doesn't equal more efficiency. With a maximum of 19.32 MT, the maximum rate is only 64.9% for London. A lot of people die inevitably given the fact that the city is densely populated. But the destruction rate is bounded by geographic constraints and uneven density, meaning that even several bombs can't guarantee complete coverage and destruction. On the contrary, Londonderry suffers a bigger rate of destruction (77%) with fewer megatons (a maximum of 370 KT). Less people die numerically, but the fact that the area is small and extremely concentrated, means that only one bomb is probably required to ensure maximum coverage. If we consider modern nuclear weapons, the yields are mostly between 150 kilotons and 1 megaton. If we use the same assumptions as before, it means an average yield of 0.575 megaton :

- For Manchester, the estimate was 1.36 million deaths. It gives us : (1.36 / 0.5) * 0.575 = 2.72 * 0.575 = 1.5 MT
- For Plymouth, the estimate was 0.21 million deaths. It gives us : (0.21 / 0.5) * 0.575 = 0.42 * 0.575 = 0.2 MT

Regarding the "allocation problem", I express it as follow :

"*The subject was not discussed earlier, but the allocations of bombs is a critical matter. Because we only have 58 bombs, but 39 cities to hit. It means something like 1.5 bombs per city, but we cannot use a fraction of a bomb. […] In fact, because of the technical requirement to create such precise weapons, and because a country can't create all possible kinds of nuclear weapons, the yield values are more arbitrary. If we try to have every possible yield value, it will require to have as many different launching systems. As an example, the US B16 Mod-3 can only have the following values : 0.3, 1.5, 60 or 170 KT. The idea is to cover most of the possible usage but not all of them (which is impossible). The same idea applies to bombs expressed as megatons.*"

The two following tables express this idea clearly. The first table shows what kind of nuclear warhead yields is required to reach the estimated required megaton value :

Key figures

City	Pop	High MT	4,5 MT	4 MT	3,5 MT	3 MT	2,5 MT	2 MT	1,5 MT	1 MT	0,5 MT
London	6,83	19,32	4	4	5	6	7	9	12	19	38
Manchester	2,34	5,95	1	1	1	1	2	2	3	5	11
Birmingham	2,28	6,58	1	1	1	2	2	3	4	6	13
Liverpool	1,95	5,10	1	1	1	1	2	2	3	5	10
Glasgow	1,65	4,72	1	1	1	1	1	2	3	4	9
Leeds	1,48	4,38	0	1	1	1	1	2	2	4	8
Sheffield	1,24	3,57	0	0	1	1	1	1	2	3	7
Newcastle	1,14	3,11	0	0	0	1	1	1	2	3	6

The other table shows how we can try to find a solution between the required megaton value, finite stockpile and geographic constraints; meaning that we are taking into account the fact that sometimes the theoretical destruction is not always guaranteed. Sometimes we are going to use more megatons

than what was planned (especially for very small cities where destruction can be largely achieved by low-hundred kiloton weapons) and sometimes we are going to have a potential mismatch given the number of available warheads and the population distribution across the conurbations (Sheffield in a nice example of a “difficult” conurbation because many settlements are very small and sprawled across a large area). Noting that some areas were already hit by some of the strikes on infrastructures (airports, ports, power plants…), possibly resulting in a fewer number of needed bombs for some cities (but this point is not directly addressed by my methodology to keep things simple) :

Key figures

City	Pop	High MT	4,5 MT	2 MT	1,5 MT	1 MT	0,5 MT	Bombs
London	6,83	19,32	4	-	-	-	-	4
Manchester	2,34	5,95	-	1	2	-	-	3
Birmingham	2,28	6,58	-	2	-	1	-	3
Liverpool	1,95	5,10	-	2	-	-	-	2
Glasgow	1,65	4,72	-	-	2	1	-	3
Leeds	1,48	4,38	-	2	-	-	-	2
Sheffield	1,24	3,57	-	1	-	1	1	3
Newcastle	1,14	3,11	-	-	2	-	-	2

Regarding some parts of NUKEMAP methodology, many things are uncertain like the shielding effect of modern buildings. A bit of inquiry on what was done to the “concrete” buildings at Hiroshima or Nagasaki doesn’t point necessarily toward better survival with bigger nuclear weapons, especially if it’s a ground burst. When you look at the extent of the damages done with conventional weapons to many military forts in Verdun region (like Douaumont fort) despite the hardening of their structures, we must be cautious about such assumptions. This is a very common issue with many nuclear war simulators : adding many variables to their model, while losing in sight usability, understanding and flexibility. To explain why the lack of transparency is problematic regarding NUKEMAP estimates, I will run three scenarios using my own results on the three cities :

- Birmingham : the initial estimate was 66.17% of destruction with 4.53–6.58 MT. Given the allocation problem, we can only use : 2 MT over Birmingham and the airport, 2 MT over Wolverhampton-Walsall, 1 MT over Southbridge
- Sheffield : the initial estimate was 65.96 % of destruction with 2.45–3.57 MT. Given the allocation problem, we can only use : 2 MT over Sheffield-Rotherham, 1 MT over Doncaster and 500 KT over Barnsley
- Plymouth : the initial estimate was 81.96 % of destruction with 0.64–0.93 MT. Given the allocation problem and because we don’t have a weapon between 0.6–0.9 MT, a 500 KT weapon is used

I choose these three scenarios because the allocated weapons match geographical constraints. Of course, some of the expected levels of destruction are not matched for several cities and conurbations (something I explained during the allocation problem : what is really achievable is tied to how many weapons are available and to our ability to account for geographical constraints) : Coventry, Portsmouth, Bournemouth… Meaning that for several cities and conurbations, destruction is concentrated in the "core" cities and/or a reduced number of locations across the conurbations :

- Coventry : only two bombs can be allocated, meaning we can only destroy Coventry (1 MT) and Rugby (500 KT) perhaps
- Bournemouth : only one bomb can be allocated, meaning we can only destroy the "core" with a 1 MT weapon
- Portsmouth : only one bomb can be allocated, meaning we can only destroy the "core" of Portsmouth with 1 MT

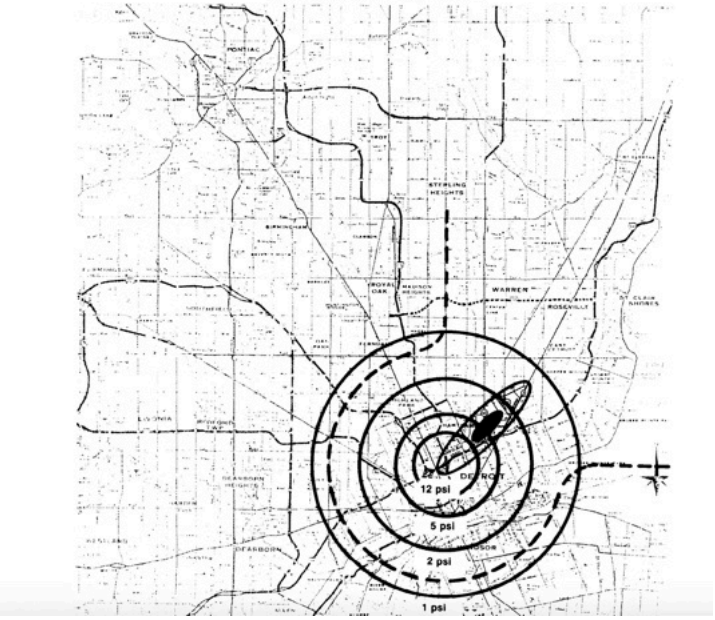
Given the fact that NUKEMAP attempts, with these scenarios, to calculate sequentially the destruction of each bomb, the algorithm breaks down when confronted with overlapping. With some manual reconstruction, the destruction rate seems to range from 35% to 55% in different configurations. For the reader, the generated maps should be read as follows (from the center of every circle to the maximum extent :

- The yellowish inner circle at the center of each detonation is the fireball
- The next grey ("dark" grey) circle is the medium damage blast radius extent
- The next orange circle is the extent of thermal radiation
- The last circle ("light" grey) is the maximum extent of light damage

Here is what my estimate looks like over Birmingham, Sheffield and Plymouth :

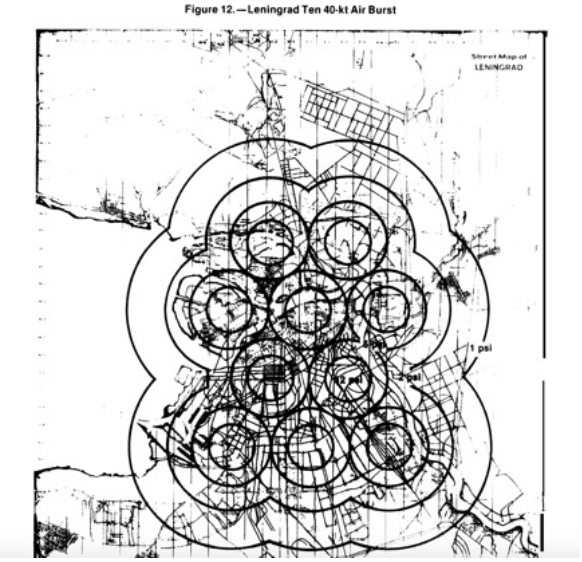
NUKEMAP seems to compensate by including "injuries" in its estimates (still providing no explanation on calculations). Given what we see with these three maps using my estimations, my personal opinion is that "injuries" estimates are highly problematic given how massive is the coverage of each weapon (whether it is a conurbation or a small city) : fireball, moderate blast destruction radius, thermal radiation, light blast destruction radius… All these things (sometimes combined with overlapping effects in conurbations) can't seriously lead to small and unrealistic estimates, especially in small cities where full coverage and even overkill is guaranteed. At this point, the survivability of this event for seriously injured people is extremely difficult (to say the least) given the potential destruction of all the infrastructures. From my perspective, all the problems come from the 1973 report used by NUKEMAP as a basis for its methodology "The Effects of Nuclear War*"*. The sole maps available inside speak for themselves (either the very outdated "one bomb = one city" or unrealistic targeting models. Here is an example with Detroit from the paper :

Figure 4.—Detroit 1-Mt Surface Burst



Another example with Leningrad :

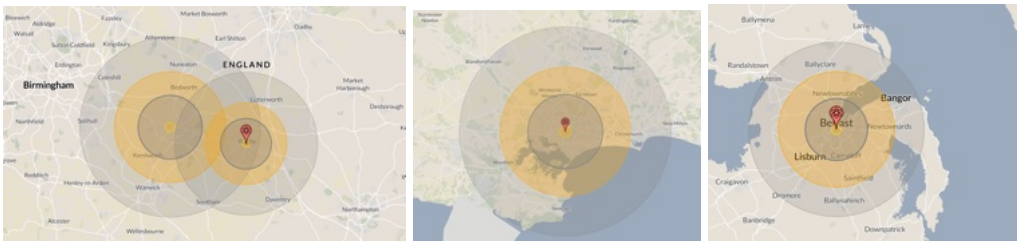
Figure 12.—Leningrad Ten 40-kt Air Burst



For transparency, here are some “sub-optimal” scenarios that emerged during the “allocation problem”; I will represent them with NUKEMAP model too :

- Coventry : the initial estimate was 68.83% of destruction with 1.34–1.95 MT. Given the allocation problem, we can only use : 1 MT over Coventry and 500 KT over Rugby
- Belfast : the initial estimate was 70.44 % of destruction with 1.42–2.06 MT. Given the allocation problem, we can only use : 2 MT over Belfast
- Bournemouth : the initial estimate was 67.05 % of destruction with 0.78–1.14 MT. Given the allocation problem, we can only use : 1 MT between Poole-Bournemouth

And their respective results over Coventry, Belfast and Bournemouth :



Regarding these “sub-optimals” scenarios, it’s important to remember that my model split the bombs between the military targets (40 bombs), the infrastructures (42 bombs) and the cities (58 bombs). Unfortunately, many of these infrastructures and military targets are within cities. It means that an optimization process could occur to increase the number of bombs available if we account for the destruction of critical infrastructures within several cities. Here is a table that summaries this issue with the number of bombs originally allocated, how much of them could be “preserved” if we account for the impact on infrastructures and how much are theoretically used based on the original allocation (in this case, nearly 15 bombs are now available) :

Key figures

Cities	Bombs	Deduced	Used	Notes
London	4	2	2	Heathrow and Biggin Hill airports
Manchester	3	1	2	Manchester airport
Birmingham	3	1	2	Birmingham airport
Liverpool	2	2	0	Liverpool port and airport
Glasgow	3	1	2	Glasgow airport
Southampton	1	1	0	Southampton airport
Belfast	1	1	0	Belfast airport and port
Coventry	2	1	1	Coventry airport
Edinburgh	2	1	1	Edinburgh airport
Portsmouth	1	1	0	Military base and port
Cardiff	1	1	0	Cardiff port
Luton	1	1	0	Luton airport
Plymouth	1	1	0	Military base and port
	25	15	10	-

Created with Datawrapper

To be more honest about NUKEMAP danger and “apparent” limitations : the fact is that the simulator always defaults to the lowest estimate. Many people will probably never notice the “Advanced options”. When you open it, you will see that the software always defaults to the optimization of the “least” destructive radius : the medium destruction range. A lot of options are also defaulted to show the least damaging scenarios : like the height of bombing. From a military perspective, setting apart the destructive range we want to optimize, air bursts for nuclear weapons are generally expected to be

between 100 and 1000 meters above the ground. Let's give a try with an 500 KT airburst over Plymouth like in my previous attempt, but this time at 1500 meters above the ground :

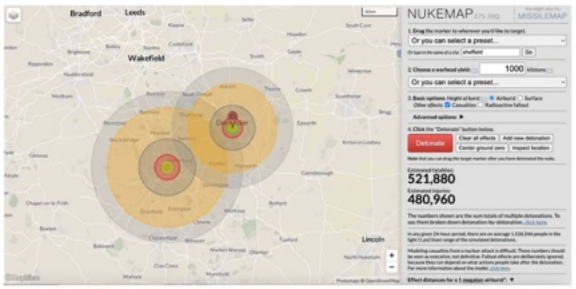
This time (when trying to do what military planners are going to do), the estimates for casualties are quite similar to my own estimates. You can also see the "heavy blast damage radius" in red; something the public will probably never see and understand. Even when you use historical nuclear weapons. So, what happens in Birmingham, Sheffield, Plymouth, Coventry and Bournemouth when we use my estimates and properly the "Advanced options" ? As a reminder :

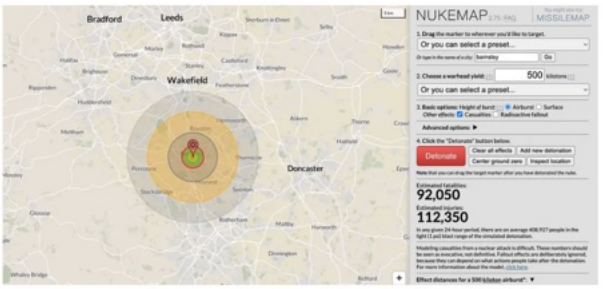
Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Low MT	High MT
Birmingham	2,28	46,2	53,8	66,2	1,51	0,77	4,53	6,58
Sheffield	1,24	45,6	54,4	66,0	0,82	0,42	2,45	3,57
Coventry	0,65	53,8	46,2	68,8	0,45	0,20	1,34	1,95
Bornemouth	0,39	48,7	51,3	67,0	0,26	0,13	0,78	1,14
Plymouth	0,26	91,3	8,7	82,0	0,21	0,05	0,64	0,93

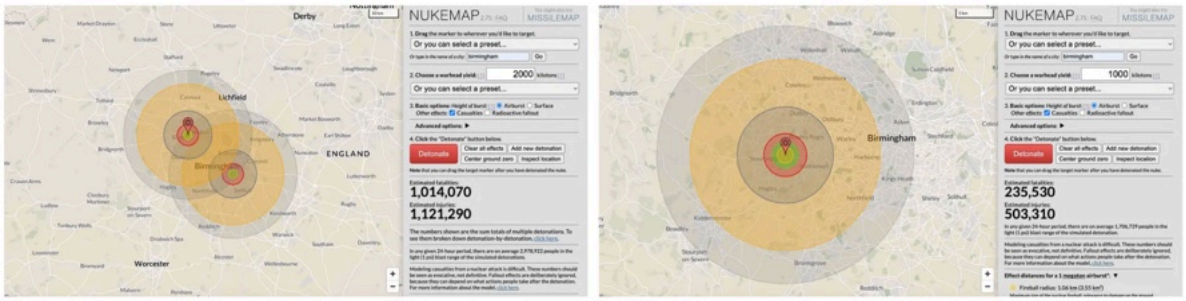
Created with Datawrapper

Because NUKEMAP can't handle overlapping, we need to do some reconstruction for Sheffield. Here are the results :

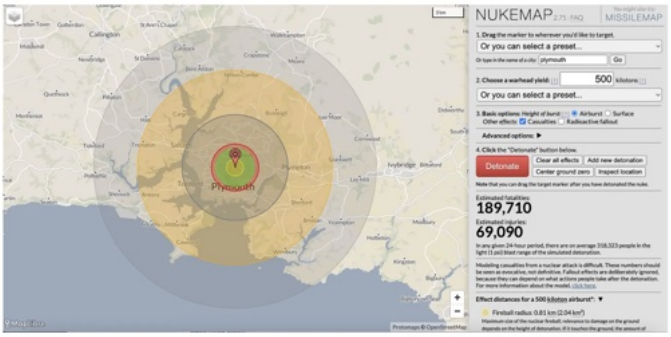




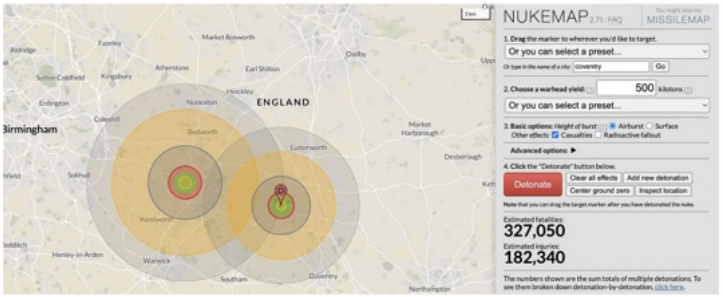
The total of deaths reached 613 000 (76% of my 800 000 estimates with my model). Same with Birmingham :



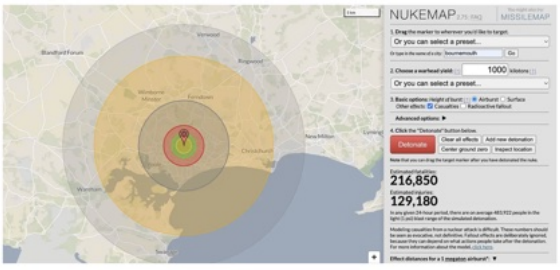
Deaths estimates reach 1.2 million (80% of my 1.5 million estimates). Here are the results for Plymouth :



The results are pretty close (90% of my 210 000 deaths with my estimates). Here is what happens with Coventry :



The total of deaths reached 327 000 deaths (72% of 450 000 deaths with my model). And finally, with Bournemouth :



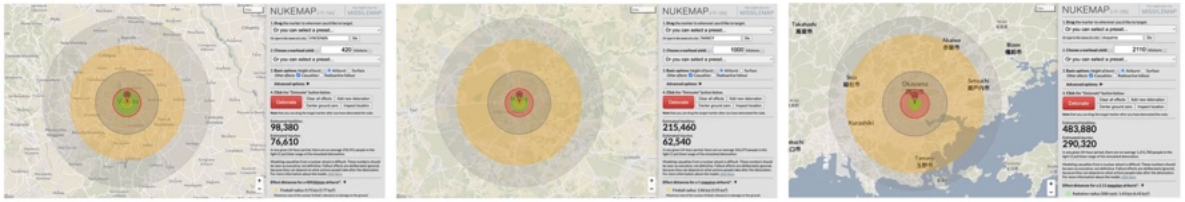
The similarity is striking (83% of 260 000 deaths with my model). Regarding what I said earlier on the “megaton estimates” formula, the consistency of the results are also noticeable when tested over cities not included in my work; and even cities outside the UK. A few examples worldwide :

Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Megaton
Vicenza (Italy)	0,115	95	5,0	83,3	0,10	0,02	0,42
Nancy (France)	0,4	20,5	79,5	57,2	0,23	0,17	1,00
Okayama (Japan)	0,7	54,3	45,7	69,0	0,48	0,22	2,11

Created with Datawrapper

And the results with NUKEMAP using the estimated megaton/kiloton value :

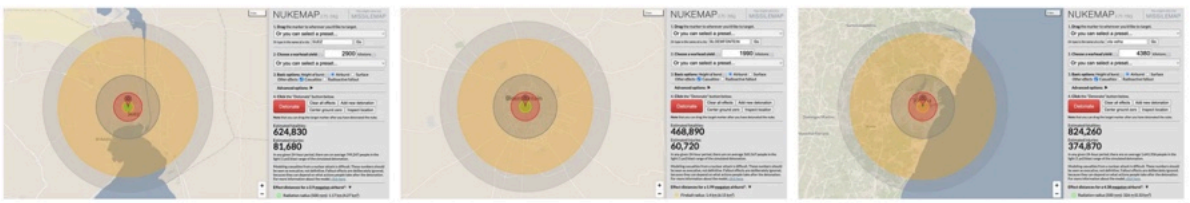


And some others with NUKEMAP visualization :

Key Figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Megaton
Suez (Egypt)	0,8	95	5,0	83,3	0,67	0,13	2,90
Bloemfontein (South Africa)	0,74	33,7	66,3	61,8	0,46	0,28	1,99
Vitoria (Brazil)	1,8	16,6	83,4	55,8	1,00	0,80	4,38

Created with Datawrapper



Without exploring the topic further, there seems to be some kind of relationship between a 1.5 MT weapon (the average used in my calculations) and the idea that 344 000 people (the average deaths per bomb) can be impacted. This formula, with the “casualties estimates” formula, seems to capture the

relationship between : urban architecture, casualties and required explosive power. Regarding the problem explained earlier with diminishing yield return, an example with the Ile de France region (or Paris metropolitan area). Here are the estimates :

Key figures

City	Pop	Core %	Urban/Metro %	Rate	Deaths	Survivors	Megaton
Greater Paris	12,1	17,2	82,8	56,0	6,78	5,32	29,56

Created with Datawrapper

And the results using NUKEMAP :

As you can see, if a single weapon can cause the expected damages, the fact is that this amount can't cover the whole area in a single strike. And also more important : this kind of weapon doesn't exist in the modern arsenal.

To conclude with NUKEMAP, a blog post by John Baker on Substack "NukeMap is considered harmful" written in 2022 raised several concerns regarding the accuracy of NUKEMAP. It took the Tsar Bomba (that NUKEMAP allows to emulate) to discuss the limits of NUKEMAP accuracy. Here is an interesting map you can find in this post :

Credit : John Baker

What does the map tell us ? That NUKEMAP seems to clearly understates the effects of one of the most massive (and documented) nuclear explosions in human history. This issue, for John Baker, raises in turn questions about how NUKEMAP is reliable or not. All this information, combined with the lack of transparent methodology, raise serious concerns.

NUCLEAR WAR SIMULATOR (NWS) is dangerously heading toward "overfitting" and "linear scaling" from Hiroshima :

"*The fatality rate curve for overpressure is adapted from "Casualty prediction comparisons" by D. I. Feinstein 1968.*

The thermal radiation curves are digitized from John S. Duffield and Frank von Hippe " The Short-term Consequences of Nuclear War for Civilians " 1984. The curves are depending on the yield of the weapon because larger weapons have longer thermal pulse duration. The individual curves were adjusted using the probability for burns at different yields in Samuel Glasstone and Philip J. Dolan "The effects of nuclear weapons", Third Edition 1977.

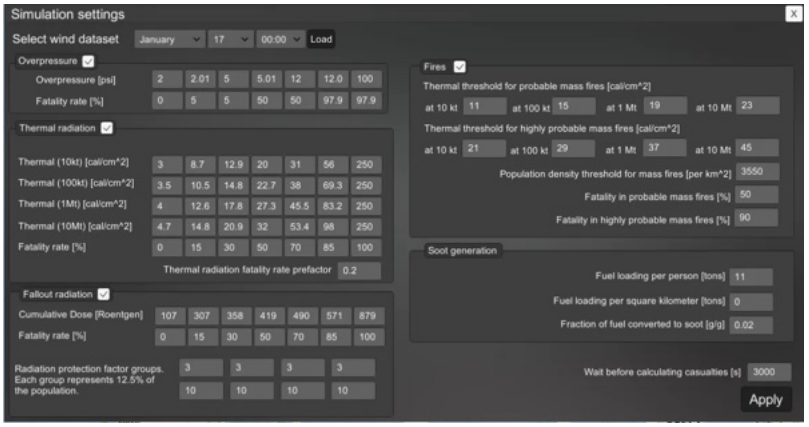
The fallout mortality rate curve is adapted from Joseph Rotblat " Approximating the Probability of Mortality Due To Protracted Radiation Exposures " 2016 (RIPD curve) assuming an LD50 of 639 cGy. The spectrum of protection factors is adapted from "Casualties Due to the Blast, Heat, and Radioactive Fallout from Various Hypothetical Nuclear Attacks on the United States" Daugherty et al. 1986.

Prompt radiation mortality rate curve is adapted from Joseph Rotblat "Acute Radiation Mortality in a Nuclear War" 1986."

More papers are added to build the methodology, but the main point is that like NUKEMAP, no clear methodology arises : which paper was used for what and how ? If mortality rate was adapted from Joseph Rotblat paper : How it was adapted and why ? Why are papers mixed and for what results ? But the biggest issue is with how to assess the results :

"*Curves defined by the user can be validated by switching into a mode which will use the population density of Hiroshima from 1945 adapted from Web Table 1 of "Population Density in Hiroshima and Nagasaki Before the Bombings in 1945", French et al American Journal of Epidemiology, Volume 187, Issue 8, August 2018*."

This is indeed both "overfitting" and "linear scaling". The very old issue I speak of earlier : it has nothing to do with curves and megatons because you can't scale with Hiroshima. Neither can you retro-engineer deaths from megaton. And because Hiroshima is a single event, this is a major mistake from a statistical perspective to use it as a validation case. When we build machine learning models, we assess the quality with multiple examples. And we even aggregate multiple runs of the same model. We can't do that with a single datapoint. This is like trying to build a linear regression model with a single point. Nagasaki (which I didn't use in my model) is here to remind us that bigger weapons didn't equal more deaths. The same issue arises with the dangerous numbers of parameters to "create" of "assess" the destructive power of a single warhead :



Source : https://nuclearwarsimulator.com/technical-details/

From a "data-analysis" perspective : we can't assess anything because the space to represent the parameters is beyond what is viewable (generally 2 or 3 dimensions). You have at least 20 parameters, with many of them sub-divided again with 7 sub-parameters. Or a total of 140 parameters with no simple way to assess them "spatially". I don't know the "gradient" possibilities regarding each thermal parameter, but because you have at least 7 parameters, you have potentially 128 subsets (this is what we call "Power Set"). At a point or another, the number of parameters is so high that there is no way to precisely understand what is happening. This is basically the best way to build an unreliable and non-understandable model as everything is "black-boxed".

On the survivability of a nuclear winter

My last paper about the "The consequences of a nuclear winter : case study on three countries in 1980s" was clear about the impossibility of extrapolating previous death estimates to apply them to an hypothetical nuclear winter :

"*What is critical following a dramatic event like a nuclear winter, is how a country is able to organize cooperation at national level, prioritize and ration the food, while accounting for the inherent and unique local challenges.*

I will account essentially for cereals because we have a crop failure rate from another similar event "Year without a summer" (1816). Cereals are also more "relatable" as it translates more easily as bread and flour, which form the core of our alimentation since millenia. It holds many advantages in terms of nutrition qualities during a famine : protein, fat, fiber, minerals like iron, zinc, magnesium… Historically, this is what is given (with soup) to starving people. For countries of the Southern Hemisphere, it translates as maize and rice too.

The minimum intake value comes from the Food and Agriculture Organization of the United Nations, which is between the required 2000 calories for adults and 1000 calories for children. A midpoint of 1500 calories. It translates as 580 grams of bread per day or 1200 grams of cooked rice. Producing 580 grams of bread requires approximately 406 grams of flour (as a reference 453 grams of bread requires 269 grams of flour, or 60%). Producing 1200 grams of cooked rice requires 480 grams of "raw" rice ("One cup/Two and a half cups" rule, as rice cooking can vary with 1:2 and 1:3 rules). Of course, people rarely eat more than 250 grams of bread (150 grams of flour required depending on recipe, or 60%-70% of total) or 300 grams of cooked rice per day (120 grams of "raw" rice required, because "raw" rice nearly triple in size when cooked), but it illustrates what could be needed in

absence of other sources of food to reach (at least) the needed calories per day. I also include maize which is a major staple food in the Southern Hemisphere. A daily intake of 250 grams of maize requires 100 grams of raw maize ("One cup/Two and a half cups" rule, similar to rice).

The temptation could be to use the estimated death rate of similar famine (like the Great Irish Famine, which fits the context as being both natural and societal) and try to extrapolate it in our case. Unlike Hiroshima where deaths were caused by an explosion of a precise size (which allows a certain level of extrapolation, if grounded in real-world constraints : density, finite stockpile, realistic targeting strategy, allocations problem…), the deaths of the Great Irish Famine have only to do with a lot of complex and intertwined reasons : crop failure, high dependency on a single source of food, undersized and inadequate relief scheme, specific Poor Law rules in 1840s Ireland…

Unfortunately, these factors are not replicable through the only use of data. They can't translate, like in my previous post on the consequences of a nuclear war on the UK, as a weighted average because it has nothing to do with urban or rural areas, or blast effect, for example.

Another fact is that many historical cases of major food shortages leave us baffled because no mass excess of deaths occurs, even below what is expected for them to occur (for example the Netherland famine in 1945 or Japan after capitulation), when the contrary happened during the Great Leap Forward or Bengal Famine. In dire situations like the Leningrad Blockade, deaths were widespread but diseases kept at bay. Theoretical resilience didn't equal practical results : under complete breakdown of front and logistics, the Soviet Union was largely able to feed its people during Operation Barbarossa. Expected social disruption didn't always occur as expected : Bengal saw no organized food riots on a large scale, contrary to what occurred on a regular basis before the famine. And when societies unravel beyond the scope of human comprehension, it's something that no data can even capture. For example during the Bengal famine : families disintegrated, child-selling occurred and people were exploited.

Many countries see a large part of their population suffering from chronic calories intake deficit (110 to 480 calories per day) without mass starvation. It leads indeed to stunted development, Kwashiorkor, scurvy, weakening of the immune system… but not to mass deaths. Famines are also never spontaneous events and effects last several years in fact, even after food production resumes. Symptoms are progressive : weakness, weight loss, related-disease and inevitably death… even with resilience and coping systems. All these things lead to an excess of deaths over the years.

For clarity, I decided to concentrate on food insecurity. To better assess the situation of each countries, the following figures will be given :

- *What was available with pre-war harvest of cereals per day and per person compared with the consequences of the nuclear winter. Of course, it represents a perfect distribution between everyone, which is not necessarily going to happen for a lot of reasons (logistics, rationing, price…)*
- *How it compares to cooking different products, depending of course on what kind of crops a country is willing to prioritize. Sometimes you have some "excess" of food available (of course, it has nothing to do with pre-war surplus, it only means that sometimes a bit more cereals are marginally available), but it's important to understand of what we are speaking of : countries trying to feed equally everyone with a simple meal, from newborns to the elderly*
- *An amount as grams of fruits and vegetables which can complement what is available of cereals*

- *Livestock is not taken into account because its survivability is difficult (as for humans) to evaluate. In such a dire situation, the following is likely going to happen : a progressive shift toward herbivores who can survive with pastures (cattle, sheep, goats…) and the progressive disappearance of "monogastric animals" (pigs, poultry…) to reroute the available cereals to human consumption. As animals don't "fail" like crops, it's possible that's in the first years we see the complete disappearance of poultry and pigs in many countries to compensate for crops failure*"

Why do I do that ? Historically famines have very few to do with "raw food" figures. It's a complex interplay of economic, cultural and political factors. Some societies are more vulnerable, but it doesn't mean that they can't find solutions. While some others can completely fail.

It was also important to avoid two major mistakes : using abstract national agricultural output and creating a threshold based on calories deficit. The latter is largely disproved by what we know from chronic calories intake deficit. That's why an effort was made to focus instead on food insecurity and translate everything as a relatable meal to get a clear picture. It's a bit "raw", but it allows us to have a comprehensive snapshot picture of the state of any nation. Here is an example :

"*With a major failure of the harvest (65–75% of the pre-war level, with a midpoint of 70%), China still has 90 millions tons of cereals (out of 300 million tons). As a comparison :*

- *300 million tons translates to 291 kilograms of cereals per year and per person, or 798 grams per day and per person*
- *90 million tons translates to 87 kilograms of cereals per year and per person, or 239 grams per day and per person*
- *It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 131 grams per day and per person*

This amount is insufficient for producing minimal levels of bread, but allow for a small excess in rice and maize (150 grams for bread, 120 grams for rice or 100 grams for maize) :

- *It's 87% of what is needed to cook 250 grams of bread (700 calories)*
- *It's 109% of what is needed to cook 300 grams of rice (400 calories)*
- *It's 131% of what is needed to cook 250 grams of maize (200 calories)*

With 65–75% of crop failure (midpoint of 70%), only 5 million tons of fruits and 20 million tons of vegetables remain (out of 18 and 68 million tons). It translates as : 13 grams of fruits and 54 grams of vegetables per day and per person."

As explained before, the reality will be more some kind of a mix of different cereals. The model is far from perfection of course. One issue with my model is that I think the shift within livestock will be quicker to increase what is given to humans. It could be interesting to add some other factors like spoilage and even the refinement costs. Regarding trade, historically, countries facing hardship tend to impose ban or control on food exports. So trade wasn't accounted for. As stocks. But that's the point of my model : people are not passive in the face of adversity, they adapt. I will add that a nuclear war won't happen out of nowhere. It will probably be the result of an escalating conflict. Basically, many countries are going to take measures to control and assess the level of many critical supplies if the threat is taken seriously : food, fuel, medication… Moreover, the escalation will likely lead to a surge

in cereal price on the international market, leading many countries to enforce strict measures for price control and stock. This was the case for example during the COVID crisis, with many countries taking such actions and banning exports, especially for staple products : Bangladesh, China, Egypt, Vietnam, Russia… Measures could also be taken to control "panic buying" locally (before and during the nuclear winter).

The famines are also so complex that all attempts to capture a pattern to predict deaths can only fail. Let's take some examples and understand why you can't use them to predict how many people will die due to a nuclear winter famine :

- Leningrad Siege (900 days) : 1 million people out of a pre-war of 2.5 million (40%). Social cohesion was maintained at all cost. Can't be linked directly to crop failure, because the population was trapped within a besieged city
- Irish Famine (7 years) : 1 million people out of 8.5 million people before the famine in Ireland (11%). Major social upheavals. Linked to multiple factors : crop failure, Poor Laws and continuous exports… Because many people leave the country (nearly 3 million people), reconstructing a percentage is not guaranteed
- Bengal Famine (1 year) : nearly 4 million people. Many demographics figures of the time are unreliable to know the exact size of the Bengal population before the famine. Linked to multiple factors : crop failure, societal disintegration, war time policies…
- Great Leap Forward (4 years) : possibly 55 million people out of 647 million people (8%). Linked to multiple factors : poor economic policies, self reliance schemes, ban from leaving affected areas…
- Soviet famine in 1930s (1 year) : possibly 9 million people primarily in today Ukraine. Difficult to assess the pre-famine population because of the destruction of many census data. Linked primarily to the collectivization process in Soviet Union

For all these reasons, we should refrain from attempts to estimate deaths for a hypothetical famine. Focusing on food insecurity and trying to understand how a society can react to such stress provide far more insights than unreliable death estimates. Regarding how to estimate the crop failure rates across the globe, the following framework was used :

"*The main idea to estimate crop failure was to use a "gradient" approach. The worst case scenario is for northernmost countries with 75% of crop failure and minimum rate of 45% for the southernmost part of the world. The logic is that most of the nuclear exchange occurred between the East and the West. It's logical for the Northern Hemisphere to be the most impacted by this event. But clouds don't move according to borders, so the idea was to take into account that less light will be available too for the Southern Hemisphere, with a progressive decrease. It's a bit of a worst-case scenario, with an average of 75% crop failure in the Northern Hemisphere, and an average of 60% in the Southern Hemisphere to account for the natural diminished effect as the clouds "move" to the southernmost part. According to the "Year without summer" data, the crop failure can even reach 90% in the northernmost part (like New-England), even if it's not an upper bound here. Also important to note that the levels of crop failure are never uniform across such large areas, as are the clouds. But let's keep things simple. It applies as follow :*

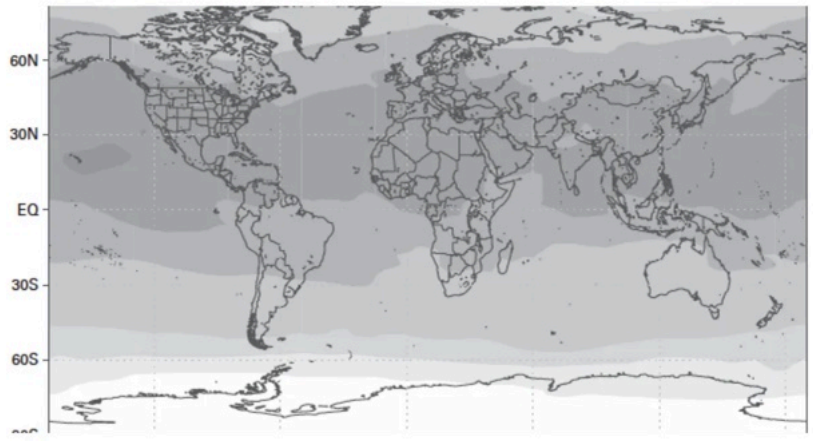
- *20°-Above 40° N (65%-75%) : Northern China and mainland China*
- *0°–20° N (55%–65%) : Southern China*
- *20°–0° S (45%–55%) : Brazil*

- *Below 20° S (45%) : South Africa*"

The framework, as simple as it is, avoids the mistake of using the same scale crop failure rate in every country. The fact is that climatic phenomena are never linear, so it was important to find a way to capture it. The framework uses basic reasoning and common sense : soot is more concentrated where nuclear bombs explode and dilute when the "clouds" move to the southern hemisphere. But due to the scale of the nuclear exchange, it was always also important to account for the idea that the impact was global. Hence the bound of 75% for the northernmost part and 45% for the southernmost part. 75% is in fact based on the "*faisceau d'indices*" method. I used this fantastic paper do draw my hypothesis (Tambora and the "Year without summer" by Bern University, which I praise for several reasons : historical depth, societal analysis, climatic modeling while acknowledging that a climatic model can't predict everything, clear understanding that famine is complex result of intertwined factors). So what we know is that :

- The rain fall were severe across Central Europe
- Prices surge and food riots were common (but not universal)
- In France violence during the crisis reach the levels of "The Great Fear" famine
- Major political effects in the United States and migration to the West
- Effects weren't uniform across continental areas : droughts in Russia, rainfall in Central Europe
- In some places, people resorted to eat horses, something you see in war time countries when food is extremely scarce
- Effects lasted several years with shift in affected regions within countries
- The extreme value of 90% of crop failure is recorded for New England during the "Year without summer"
- Possibly 100 000 deaths worldwide

All these clues point toward something like 30–60 percent of crop failure with huge regional variations (perhaps less, perhaps more). Hence the bound of 45%–75% in my scenario. Something described by nuclear war studies on nuclear winter. An example :



Global smoke distribution from a 100-warhead nuclear exchange between India and Pakistan one month after the event. Darker shading indicates greater sunlight absorption. This map assumes that 5 million tons of soot was injected into the air, almost the same mass as the Great Pyramid of Giza.

The paper "*Global food insecurity and famine from reduced crop, marine fishery and livestock production due to climate disruption from nuclear war soot injection*" by Lili Xia et al, thinks it's possible. For example, the paper estimated that 255 million people will die following a nuclear exchange representing 5 TG of soot, especially because of famine. Their methodology is as follow :

"*We conducted a study using multiple crop models for rice, wheat, maize, and soybeans, showing that the impacts from 5 Tg of soot injected into the upper atmosphere would have global repercussions (Jägermeyr et al., 2020). Total single-year losses of 12 (±4) % quadruple the largest observed historical anomaly and exceed impacts caused by historic droughts and volcanic eruptions. Integrated food trade network analyses showed that domestic reserves and global trade could largely buffer the production anomaly in the first year. Persistent multiyear losses, however, would constrain domestic food availability and propagate to the Global South, especially to food-insecure countries. By year 5, maize and wheat availability would decrease by 13 % globally and by more than 20 % in 71 countries with a cumulative population of 1.3 billion people. In view of today's high level of nuclear risks, this study shows that a regional conflict using <1 % of the worldwide nuclear arsenal could have adverse consequences for global food security unmatched in modern history*."

The idea that 12% of crops lost is the highest ever seen in history is not realistic when you know : the "Year without summer", crop failure rate during Irish Famine... As explained before, the first years will see many countries banning exports and enforcing rationing on food. What is more logical is a decrease of international trade in the first years, and then a progressive return. In reality, things are going to be even more complex. If staple foods won't be exported, some other agricultural products can still be exported. Some forms of barter economy can arise too between some countries, like exchanging oil for food for example.

Let's do what I do in my paper on the whereabouts of the Southern Hemisphere with their methodology (or 35% of harvest lost over 6 years) with China. In 1983—to align with my previous paper tone—China produced 300 million tons of cereals, and had 1.03 billion inhabitants. With a major failure of the harvest (35% of the pre-war level), China still has 195 million tons of cereals (out of 300 million tons). As a comparison:

- 300 million tons translates to 291 kilograms of cereals per year and per person, or 798 grams per day and per person
- 195 million tons translates to 189 kilograms of cereals per year and per person, or 518 grams per day and per person
- After accounting for animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage), this leaves 285 grams per day and per person

This amount is largely sufficient for producing minimal levels of bread, rice, or maize (150 grams for bread, 120 grams for rice or 100 grams for maize) :

- It's 190% of what is needed to cook 250 grams of bread (700 calories)
- It's 238% of what is needed to cook 300 grams of rice (400 calories)
- It's 285% of what is needed to cook 250 grams of maize (200 calories)

If we apply their methodology carefully, this is even "better", because we have the loss of the first year (15%) or 255 million tons of cereals available. Then if we apply the failure rate after 5 years (20%), China production will settle at 204 million tons of cereals. This is far from near-extinction level for China. Another method used to reproduce their result is to understand the 20% loss over five

years, as a total amount of loss. To understand it, after first year (15% initial loss) here is what remains :

- 300 × (1–0.15) = 300 × 0.85 = 255 million tons

Then for the next 5 years (20% of cumulative loss), with 4% loss each year:

- Year 1: 255 × (1–0.04) = 244.8 million tons
- Year 2: 244.8 × (1–0.04) = 235.0 million tons
- Year 3: 235.0 × (1–0.04) = 225.6 million tons
- Year 4: 225.6 × (1–0.04) = 216.6 million tons
- Year 5: 216.6 × (1–0.04) = 207.9 million tons

It's even better than the two previous scenarios used. In the three cases, the amount of food available is substantial to avoid starvation. Let's apply the logic to the worldwide population in 1983 or 4.6 billion people. With a major failure of the harvest (35% of the pre-war level), global production still has 910 million tons of cereals (out of 1.4 billion tons). As a comparison:

- 1.4 billion tons translates to 304 kilograms of cereals per year and per person, or 833 grams per day and per person
- 910 million tons translates to 198 kilograms of cereals per year and per person, or 542 grams per day and per person
- After accounting for animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage), this leaves 298 grams per day and per person

This amount is largely sufficient for producing minimal levels of bread, rice, or maize (150 grams for bread, 120 grams for rice or 100 grams for maize):

- It's 199% of what is needed to cook 250 grams of bread (700 calories)
- It's 248% of what is needed to cook 300 grams of rice (400 calories)
- It's 298% of what is needed to cook 250 grams of maize (200 calories)

If we apply their methodology carefully, this is even "better", because we have the loss of the first year (15%) or 1.19 billion tons of cereals available. Then if we apply the failure rate after 5 years (20%), global production will settle at 970 million tons of cereals. This is far from near-extinction level for humanity. Another method used to reproduce their result is to understand the 20% loss over five years, as a total amount of loss. To understand it, after first year (15% initial loss) here is what remains:

- 1.4 billion × (1–0.15) = 1.4 billion × 0.85 = 1.19 billion tons

Then for the next 5 years (20% of cumulative loss), with 4% loss each year:

- Year 1: 1.19 billion × (1–0.04) = 1.142 billion tons
- Year 2: 1.142 billion × (1–0.04) = 1.096 billion tons
- Year 3: 1.096 billion × (1–0.04) = 1.052 billion tons
- Year 4: 1.052 billion × (1–0.04) = 1.010 billion tons
- Year 5: 1.010 billion × (1–0.04) = 970 million tons

It's even better than the two previous scenarios used. In the three cases, the amount of food available is substantial to avoid starvation. We need to account for distribution of course, which is not the case in my calculations. But the very fact is that we can't estimate any deaths based solely on this indicator. And past famines offer no clues on why people die or survive during major food shortages. At least, not solely on crop failure rates and calories intake.

Of course, this reasoning from my part is a bit of "absurdity" and extreme denial of their work, which uses a far more sophisticated climate modeling system than mine and also introduces some levels of granularity regarding specific crop failure rates.

But the fact remains that the paper by Lili Xia et al. offers no clues on the methodology used to calculate deaths (at least in their original paper), apart from some sort of inferred calories threshold; which is not the most optimal solution given our knowledge of past famines and today's food insecurity.

Given the fact that Lili Xia et al. paper uses more recent data, we can do the same calculations for China with 1.4 billion people and 658 million tons of cereals. Here are the results :

With a major failure of the harvest (65–75% of the pre-war level, with a midpoint of 70%), China still has 197.4 million tons of cereals (out of 658 million tons). As a comparison:

- 658 million tons translates to 470 kilograms of cereals per year and per person, or 1,288 grams per day and per person
- 197.4 million tons translates to 141 kilograms of cereals per year and per person, or 386 grams per day and per person
- It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 212.3 grams per day and per person

This amount is sufficient for producing minimal levels of bread, rice, and maize (150 grams for bread, 120 grams for rice or 100 grams for maize):

- It's 141.5% of what is needed to cook 250 grams of bread (700 calories)
- It's 176.9% of what is needed to cook 300 grams of rice (400 calories)
- It's 212.3% of what is needed to cook 250 grams of maize (200 calories)

With a 70% crop failure rate, it means that only 72 million tons of fruit and 178 million tons of vegetables remain (out of 242 and 594 million tons) : 140 grams of fruits and 346 grams of vegetables per day and per person.

It's also important to state that the idea of a "nuclear winter" with huge and lasting effects is highly debated; and even contested for good reasons. I will also add that from a natural perspective, all volcano eruptions don't always result in "Year without summer".

From my point of view, the paper commit the very same error as NWS and NUKEMAP do on nuclear bombs impact; because of their reliance on extremely dense formula to express the caloric intake deficit :

Calorie calculations. For the *Livestock* case, national-level available calories are calculated by

$$\begin{aligned} C_L = {} & C_{\text{plantbased}} \times \left(1 - R_{\text{cy}}\right) + C_{\text{livestock-ruminant}} \times \left(1 - R_{\text{grass}}\right) \\ & + C_{\text{livestock-monogastric}} \times \left(1 - R_{\text{cy}}\right) + C_{\text{livestock-monogastric}} \\ & \times R_{\text{grass}} \times \left(1 - R_{\text{cy}}\right) \times \frac{F_{\text{ruminant-cropfeed}}}{F_{\text{monogastric-cropfeed}}} \\ & + C_{\text{aquaculture}} \times \left(1 - R_{\text{cy}}\right) + C_{\text{marine-catch}} \times \left(1 - R_{\text{marine-catch-}y}\right) \\ & + \left(1 - R_{\text{cy}}\right) \times C_{\text{plantbased}} \times \frac{f_{\text{final-product-biofuel}}}{f_{\text{food}}} \end{aligned} \tag{4}$$

where C_L is calories available in each nation L (kcal per capita per day) under the *Livestock* case, $C_{\text{plantbased}}$, $C_{\text{livestock-ruminant}}$ and $C_{\text{livestock-monogastric}}$ are calories available from plant-based products, ruminants and monogastrics[27] and $C_{\text{aquaculture}}$ and $C_{\text{marine-catch}}$ are calculated by calorie availability from fish[27] multiplied by the ratio of aquaculture and catch[46]. R_{grass} is grass production change, and $R_{\text{marine-catch-}y}$ is marine capture change. $F_{\text{ruminant-cropfeed}}$ is the fraction of crop feed for ruminant, and $F_{\text{monogastric-cropfeed}}$ is the fraction of crop feed for monogastrics[26]. R_{cy} is crop production change calculated as:

$$w_{\text{iy}} = \frac{P_i c_i R_{\text{iy}}}{\sum_{i=1}^{4} P_i c_{iR_{\text{iy}}}}, \tag{5}$$

and

$$R_{\text{cy}} = \sum_{i=1}^{4} R_{\text{iy}} w_{\text{iy}} \tag{6}$$

where index i is maize, rice, soybean or wheat, w_{iy} is the calorie weight of each commodity per country each year, P_i is the national production of item i in FAO-CBS[47], c_i is calories per 100 g retail weight for each item[23] and R_{iy} is national production change (%) of each item in year y after the nuclear wars. $f_{\text{final-product-biofuel}}$ is the fraction of final product of biofuel in plant-based product, and f_{food} is the fraction of food in plant-based product.

For the *No Livestock* case, national-level available calories are calculated by

$$\begin{aligned} C_{\text{NL}} = {} & C_{\text{plantbased}} \times \left(1 - R_{\text{cy}}\right) + C_{\text{marine-catch}} \times \left(1 - R_{\text{marine-catch-}y}\right) \\ & + C_{\text{plantbased}} \times f_{\text{feed-to-food}} \times \left(1 - R_{\text{cy}}\right) \times p_{\text{feed-for-human}} \\ & + \left(1 - R_{\text{cy}}\right) \times C_{\text{plantbased}} \times \frac{f_{\text{final-product-biofuel}}}{f_{\text{food}}} \end{aligned} \tag{7}$$

C_{NL} is national-level available calories in the *No Livestock* case. $f_{\text{feed-to-food}}$ is the fraction of food crops that are used as feed relative to their usage as food, calculated based on their calorie content[26]. $p_{\text{feed-for-human}}$ is the percentage of livestock grain feed used for human consumption. We tested 0%, 20%, 40%, 50%, 60%, 80% and 100% and used 50% for Table 2 and Fig. 4.

For the *Partial Livestock* case, national-level available calories are calculated by

$$\begin{aligned} C_{\text{PL}} = {} & C_{\text{plantbased}} \times \left(1 - R_{\text{cy}}\right) + C_{\text{marine-catch}} \times \left(1 - R_{\text{marine-catch-}y}\right) \\ & + C_{\text{plantbased}} \times f_{\text{feed-to-food}} \times \left(1 - R_{\text{cy}}\right) \times p_{\text{feed-for-human}} \\ & + (1 - p_{\text{feed-for-human}}) \times \left(C_{\text{livestock-ruminant}} \times \left(1 - R_{\text{grass}}\right)\right. \\ & + C_{\text{livestock-monogastric}} \times \left(1 - R_{\text{cy}}\right) \\ & \left. + C_{\text{livestock-monogastric}} \times R_{\text{grass}} \times \left(1 - R_{\text{cy}}\right) \times \frac{F_{\text{ruminant-cropfeed}}}{F_{\text{monogastric-cropfeed}}}\right) \\ & + \left(1 - R_{\text{cy}}\right) \times C_{\text{plantbased}} \times \frac{f_{\text{final-product-biofuel}}}{f_{\text{food}}} \end{aligned} \tag{8}$$

C_{PL} is national-level available calorie in *Partial Livestock* case. On the basis of the assumed percentage of livestock crop feed to convert to human consumption, instead of wasting the remaining portion of livestock crop feed as in *No Livestock* case, here we use the remaining livestock crop feed to raise livestock.

The percentage of national household waste is calculated by

$$P_{\text{waste}} = 100\% \times \frac{C_{\text{available}} - C_{\text{intake}}}{C_{\text{available}}} \tag{9}$$

P_{waste} is the percentage of national household waste of food calorie availability in 2010, $C_{\text{available}}$ is the food calorie availability per day per person in each country and C_{intake} is the national calorie intake per day per person[27].

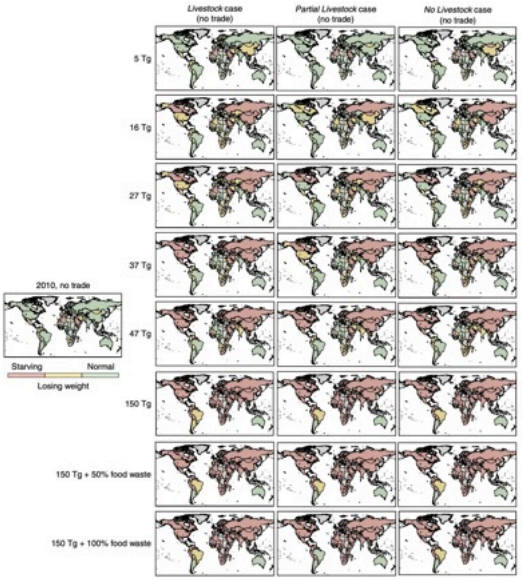
Source : “Global food insecurity and famine from reduced crop, marine fishery and livestock production due to climate disruption from nuclear war soot injection” by Lili Xia et al (2022)

I express serious concerns too with some of the broad assumptions (like death estimates from an hypothetical nuclear conflict like if deaths can be deduced from a big and abstract megaton value worldwide, or generalized starvation levels in countries) made by their paper :

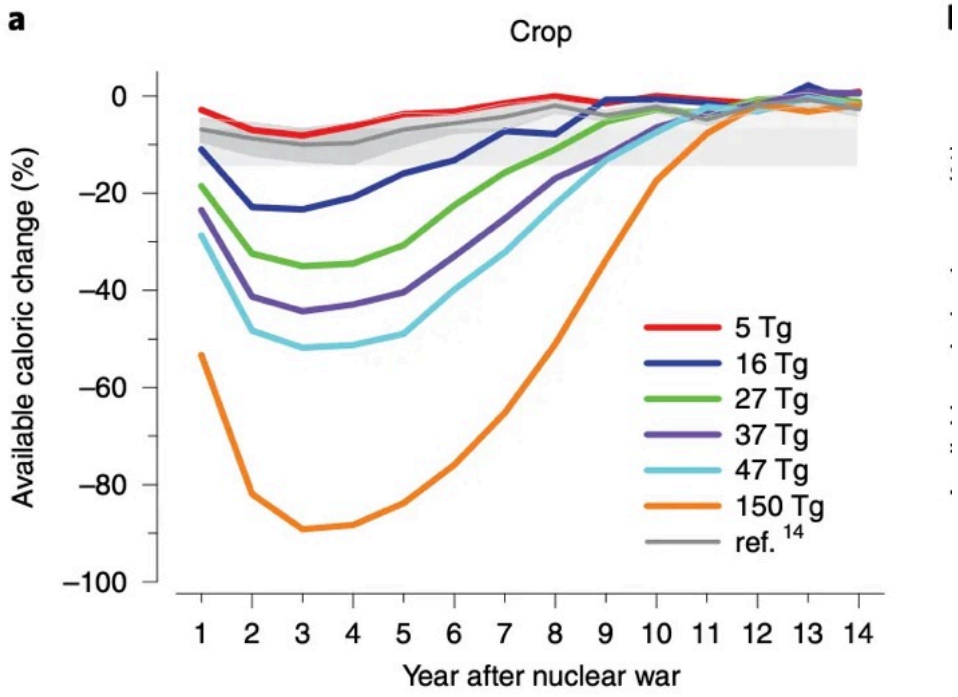
Table 1 | Number of weapons on urban targets, yields, direct fatalities from the bomb blasts and resulting number of people in danger of death due to famine for the different scenarios we studied

Soot (Tg)	Number of weapons	Yield (kt)	Number of direct fatalities	Number of people without food at the end of Year 2
5	100	15	27,000,000	255,000,000
16	250	15	52,000,000	926,000,000
27	250	50	97,000,000	1,426,000,000
37	250	100	127,000,000	2,081,000,000
47	500	100	164,000,000	2,512,000,000
150	4,400	100	360,000,000	5,341,000,000
150	4,400	100	360,000,000	*5,081,000,000

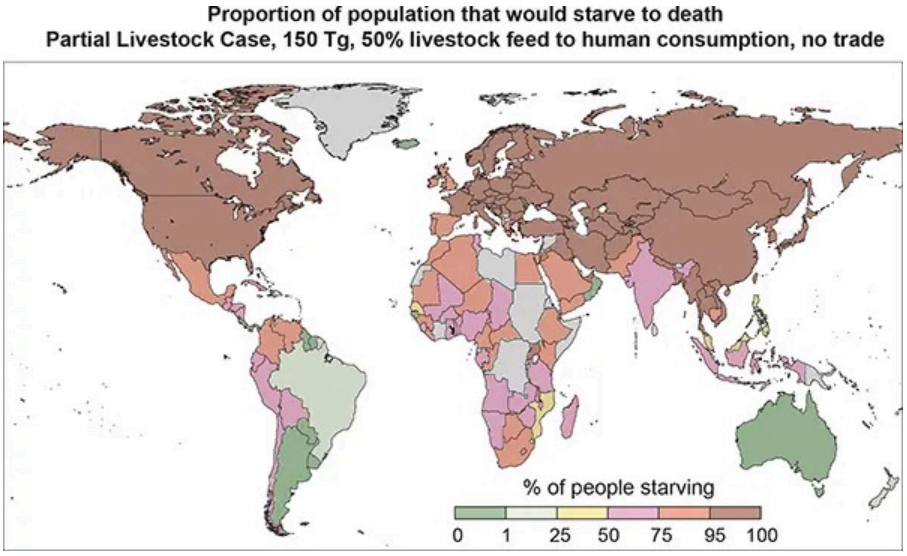
The 5 Tg case scenario is from ref. [16] for an India–Pakistan war taking place in 2008; the 16–47 Tg cases are from ref. [18] for an India–Pakistan war taking place in 2025; and the 150 Tg case is from ref. [17], which assumes attacks on France, Germany, Japan, United Kingdom, United States, Russia and China. The last column is the number of people who would starve by the end of Year 2 when the rest of the population is provided with the minimum amount of food needed to survive, assumed to be a calorie intake of 1,911 kcal per capita per day, and allowing for no international trade; from Supplemental Information, Supplementary Table 5, the Partial Livestock case, in which 50% of livestock grain feed is used for human consumption, and 50% of livestock grain feed is used to raise livestock, using the latest complete data available for the year 2010. For 2010, the total population of the nations used in this study was 6,700,000,000. There are many other scenarios in which these amounts of soot could be produced by a nuclear war, and the scenarios we use are only meant to be illustrative examples. The last column is the case with the fewest number of deaths without international trade, and other cases are available in the Supplementary Information. *Assuming total household waste is added to food consumption.



The Lili Xia et al. paper seems to be "obsessed" with the caloric intake threshold, despite its unreliability as a single factor of deaths during famine. This table speaks for itself :



In 2023, Lili Xia and several authors published the following paper "*Opinion: How fear of nuclear winter has helped save the world, so far*" with a map explaining that in case of massive crop failure rate worldwide and no trade, Iceland will see only 10% of starvation rate. The map :



Let's do the math (Iceland has 360,000 inhabitants), using the same framework as for China (noting that many countries don't produce rice or even maize) :

"With a major failure of the harvest (65–75% of the pre-war level, with a midpoint of 70%), Iceland still has 2,802.9 tons of cereals (out of 9,343 tons). As a comparison:

- *9,343 tons translates to 26 kilograms of cereals per year and per person, or 71.2 grams per day and per person*
- *2,802.9 tons translates to 7.8 kilograms of cereals per year and per person, or 21.4 grams per day and per person*
- *It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 11.8 grams per day and per person*

This amount is insufficient for producing minimal levels of bread, rice, and maize (150 grams for bread, 120 grams for rice or 100 grams for maize):

- *It's 7.9% of what is needed to cook 250 grams of bread (700 calories)*
- *It's 9.8% of what is needed to cook 300 grams of rice (400 calories)*
- *It's 11.8% of what is needed to cook 250 grams of maize (200 calories)*

With a 70% crop failure rate, it means that only 1,395 tons of vegetables remain (out of 4,650 tons): 3.88 kilograms of vegetables per year and per person, or 10.6 grams of vegetables per day and per person."

At this point there is no reasonable possibility to organize a rationing system and the next harvest. The sole reliance on livestock is only a very short term solution. It has nothing to do with efficiency but only with climatic and physical constraints. Several cases were tested:

- Oman: similar survivability as Iceland
- Algeria: can fare better than China
- South Africa: mass starvation in the range of Algeria
- Mali: better than South Africa and Algeria but lower than Oman and Iceland

Here is the raw snapshot for Oman (5.28 million people):

"With a major failure of the harvest (65–75% of the pre-war level, with a midpoint of 70%), Oman still has 60,000 tons of cereals (out of 200,000 tons). As a comparison:

- *200,000 tons translates to 37.9 kilograms of cereals per year and per person, or 103.8 grams per day and per person*
- *60,000 tons translates to 11.4 kilograms of cereals per year and per person, or 31.1 grams per day and per person*
- *It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 17.1 grams per day and per person*

This amount is insufficient for producing minimal levels of bread, rice, and maize (150 grams for bread, 120 grams for rice or 100 grams for maize):

- *It's 11.4% of what is needed to cook 250 grams of bread (700 calories)*
- *It's 14.3% of what is needed to cook 300 grams of rice (400 calories)*
- *It's 17.1% of what is needed to cook 250 grams of maize (200 calories)*

With a 70% crop failure rate, it means that only 250,800 tons of vegetables remain (out of 836,000 tons) and 150,000 tons of fruits remain (out of 500,000 tons): 130.2 grams of vegetables and 77.9 grams of fruits per day and per person."

Here is the snapshot for Algeria (46 million people):

"With a major failure of the harvest (65–75% of the pre-war level, with a midpoint of 70%), Algeria still has 1.56 million tons of cereals (out of 5.21 million tons). As a comparison:

- *5.21 million tons translates to 113.3 kilograms of cereals per year and per person, or 310.4 grams per day and per person*
- *1.56 million tons translates to 33.9 kilograms of cereals per year and per person, or 92.9 grams per day and per person*
- *It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 51.1 grams per day and per person*

This amount is insufficient for producing minimal levels of bread, rice, and maize (150 grams for bread, 120 grams for rice or 100 grams for maize):

- *It's 34.1% of what is needed to cook 250 grams of bread (700 calories)*
- *It's 42.6% of what is needed to cook 300 grams of rice (400 calories)*
- *It's 51.1% of what is needed to cook 250 grams of maize (200 calories)*

With a 70% crop failure rate, it means that only 2.4 million tons of vegetables remain (out of 8 million tons) and 2.1 million tons of fruits remain (out of 7 million tons): 143 grams of vegetables and 125 grams of fruits per day and per person."

Here is the snapshot for South Africa (63 million people):

"With a major failure of the harvest (65–75% of the pre-war level, with a midpoint of 70%), South Africa still has 5.4 million tons of cereals (out of 18 million tons). As a comparison:

- *18 million tons translates to 285.7 kilograms of cereals per year and per person, or 783 grams per day and per person*
- *5.4 million tons translates to 85.7 kilograms of cereals per year and per person, or 235 grams per day and per person*
- *It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 129 grams per day and per person*

This amount is sufficient for producing minimal levels of bread, rice, and maize (150 grams for bread, 120 grams for rice or 100 grams for maize):

- *It's 86.0% of what is needed to cook 250 grams of bread (700 calories)*
- *It's 107.5% of what is needed to cook 300 grams of rice (400 calories)*
- *It's 129.0% of what is needed to cook 250 grams of maize (200 calories)*

With a 70% crop failure rate, it means that only 0.9 million tons of vegetables remain (out of 3 million tons) and 2.1 million tons of fruits remain (out of 7 million tons): 39.2 grams of vegetables and 91.3 grams of fruits per day and per person."

And the final snapshot for Mali (23.2 million people):

"With a major failure of the harvest (65–75% of the pre-war level, with a midpoint of 70%), Mali still has 3.06 million tons of cereals (out of 10.2 million tons). As a comparison:

- *10.2 million tons translates to 439.7 kilograms of cereals per year and per person, or 1,205 grams per day and per person*
- *3.06 million tons translates to 131.9 kilograms of cereals per year and per person, or 361 grams per day and per person*
- *It's important to account for the need to sustain animal consumption, storage and seeds (mix of 20% of seeds, 20% for animal consumption and 5% for storage) or 198.6 grams per day and per person*

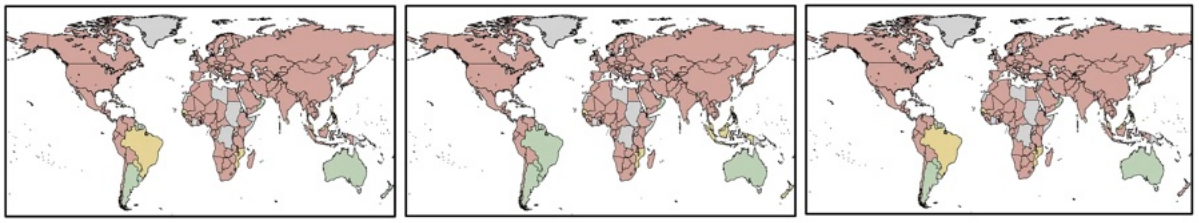
This amount is sufficient for producing minimal levels of bread, rice, and maize (150 grams for bread, 120 grams for rice or 100 grams for maize):

- *It's 132.4% of what is needed to cook 250 grams of bread (700 calories)*
- *It's 165.5% of what is needed to cook 300 grams of rice (400 calories)*
- *It's 198.6% of what is needed to cook 250 grams of maize (200 calories)*

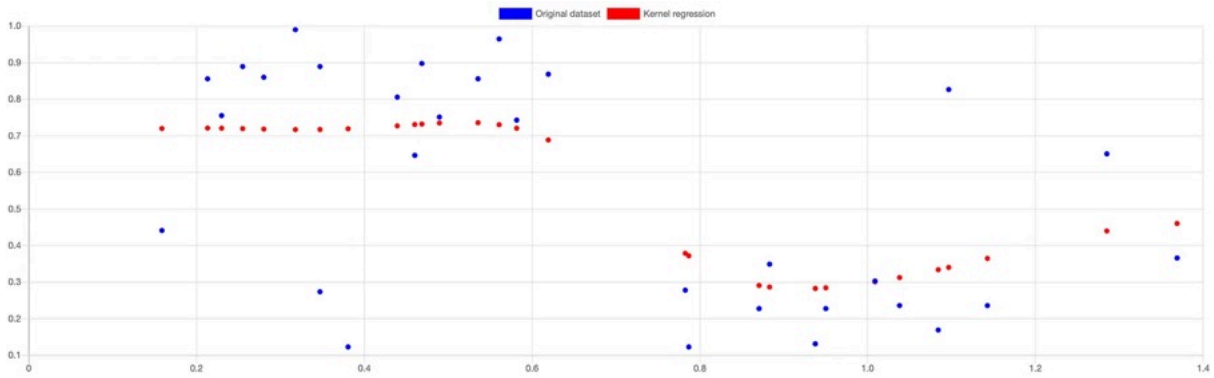
With a 70% crop failure rate, it means that only 0.75 million tons of vegetables remain (out of 2.5 million tons) and 0.69 million tons of fruits remain (out of 2.3 million tons): 88.7 grams of vegetables and 81.6 grams of fruits per day and per person."

As I said earlier : these are "raw" snapshots. What they illustrate is the extreme heterogeneity of agricultural systems (and potential resilience) across the world. The reasoning used by the Lili Xia et

al paper is confirmed in their 2022 publication (three scenarios with livestock variations and no trade assumptions; 150 TG of soot; Iceland and Oman still in green) :



Like with many methods over reliant on too many parameters, there is no guarantee of accuracy and understanding of what the formula does exactly. To illustrate the point, here is a complex non linear problem to solve :



What we want to do is to capture the relationship between all the blue datapoints. We can see that they form some kind of a wave with several outliers. The solution to achieve it is using “Kernel regression”, because we can’t build a straight line across the datapoints. The result is some sort of an “averaging curve” with red dots. The complexity is understood in “broad” terms (we are able to capture the “wave”) but at the cost of ignoring potential useful cases (some “outliers” for example), to focus on the general trend. Of course, it could perfectly work for real cases scenarios with few parameters like housing prices, body mass or predicting students performances. But when it comes to estimating deaths from famines, a “general trend” is not workable as explained earlier because the “general trend” (which is not guaranteed to exist in the first place) misses the underlying complexity, parameters and unpredictable outcomes of the topic.

So what can we do to assess the survival of different countries ? My paper proposed to use historical and political context to understand how the collapse of trade routes and the nuclear winter can impact their survivability. By focusing on three countries (China, South Africa and Brazil) it was easier to build comprehensive scenarios. Something you can’t do when you work on broad assumptions without accounting for the inherent and unique local challenges. In my paper :

- China suffered the worst harvest loss (70%), but benefited from a highly centralized system and will still be able to produce fuel in large quantities, and will likely accept a strategic abandonment of the western regions above the “Heihe–Tengchong Line”
- South Africa has more food than China (harvest loss at 45%), but the level of social upheaval and the absence of fuel production will seriously complicate its outcome, forcing the country to abandon South West Africa and major parts of mainland South Africa

- Brazil is more of an intermediate scenario with available food (50% of the harvest lost) and some fuel production, but many challenges await ahead with the high levels of urbanization and unsustainability of Amazonian region

In all cases, it was hypothesized that at one point or another these countries will have to abandon a sizable portion of their territory to focus on key areas. Possible scenarios involving regional shifts were included to account for how countries can interact with their neighbors. The paper concludes by a possible rationing system to allow China to survive. The conditions are harsh, with perhaps only 300–400 grams of food per day, but with a clear emphasis on why societies need to find a way to stay "tight-knit" :

"*The initial stock before seeds, animal consumption and storage was 90 million tons of cereals. With 45% for this task, 55% remain for human consumption or 49 million tons. What we need is to find a nice balance between the need to care for the youngest and allow workers to work without being too exhausted, while not abandoning the elderly. Even it proves insufficient. History shows us that when we abandon the weakest, societies inevitably unravel beyond recognition. This "equitable" distribution is a bit optimistic when we know from history that in dire situations, we unfortunately tend to abandon the weakest. It works as follow :*

- *The very young will receive 240 grams of cooked rice per day. Or 96 grams of raw rice. It could possibly represent 10% of the population in 1983, or 103 million people. It represents 3 609 120 000 000 grams a year, or 3.6 million tons of cereals*
- *The very old accounted perhaps for something like 5% of the population, or 52 million people. Their ration is fixed at 240 grams of cooked rice per day. Or 96 grams of raw rice per day. It translates as 1 822 080 000 000 grams per year, or 1.8 million tons of cereals*
- *What remains of the population (875 million people) will get what remains of the cereals, or 43.6 million tons of cereals. It represents 43 600 000 000 000 grams. It represents 49 kilograms per person and per year. It represents 134 grams of raw rice per day, or 335 grams of cooked rice per day.*

Fruits could be given to everyone, but past cases show that fruits are generally given to children to compensate for lack of food and because they are growing. In 1983, the children between 0 and 9 years old represented something like 21% of the Chinese population (or 216 million people). 5 million tons of fruits are still available. It represents 5 000 000 000 000 grams, and it translates as 23 kilograms per year, and 63 grams per day and per child.

Vegetables can be given to everyone to compensate for the lack of other food and ensure some diversity in food intake, even if it represents only 54 grams per person and per day.

Regarding meat consumption, I said earlier that animals don't "fail" like crops. I didn't account for them, but there is no reason for animals to suddenly disappear from China during the nuclear winter. As a basis, China consumed something like 13 million tons of meat in 1983. Applying the same failure rate as for crops would be a total nonsense, as meat consumption is probably going to increase. It will represent 13 000 000 000 000 grams of meat. Divided by the whole population, it means that everyone can get 12 kilograms per year, or 33 grams of meat everyday. This is more likely to come as something like 231 grams of meat every week."

Of course, what is going to be given to people is more a mix of different cereals; but you got the idea. It has nothing to do with being kind, but just thinking realistically on how countries will adapt to

survive, even in a diminished form. Contrary to many models which assume total passivity, the fact is that we have never seen humans doing nothing in the face of adversity. Because if such a catastrophic event should happen, we should have a clear understanding of what it means and how to handle “at best” the situation, with a plan for survivors.

A few words

As the three papers I wrote were originally published on the subreddit r/Threads1984, here is what I said about my reasons to write them and what dictate my reasoning :

The first reason is that I’m profoundly appalled by the lack of transparency of many academic papers/models who predict inflated figures without even explaining how they obtain them, and hiding behind abstract ideas of « curves », academic credentials and obscure papers. Something that is unacceptable, especially when we tackle this subject. My three posts are far from perfection, but at least everyone can understand, follow and replicate the logic behind the figures; and even criticize them if they want.

The second is my profound disdain for « doomsday » hype in many academic circles. There is something weird about educated people having such a loathsome point of view on what humanity is able to do in face of adversity.

When academics for example gloss over the deaths of « 5 billion people » after the failure of the post nuclear war harvest and seem so happy to produce such unrealistic and unbelievable figures, many questions arise. Did they understand what it would mean for all these people ? The slow, painful and unfair process leading to death ? Probably not.

In fact, few people will die when the bombs fall on cities. Many will survive in a devastated world. When everyone vanishes like in the average « doomsday » academic model, there are no ethical or moral dilemmas. This is very comfortable. You don’t ask yourself how to use fuel or to distribute food, because everyone is dead. When you know that many people are going to survive, all these questions suddenly arise. Because the post-nuclear war world is in fact a « messy » one.

Humans will endure critical conditions and have to answer impossible questions. This is what I was willing to show in my work : cascading failures and bad choices leading to governance collapse, permanent trade-offs on how to allocate food/fuel, ethical/moral dilemmas to know who is going to live or die, abandonment of large parts of countries because of unsustainable conditions… Not everyone will survive because it’s unlikely, not everyone will die because it’s total denial of human dignity and ingenuity. This is in fact the painful « middle » way.

These are the two pitfalls of nuclear war studies : the naive « David Brin’s Postman » model (even if I agree with David Brin’s core message : societal collapse has sometimes more to do with “predating” forces following a disaster, than the disaster by itself) and the « doomsday » academic hype. The fact is that what can happen after such an event is largely beyond the scope of our comprehension and available data. Many things are not predictable like how many people will die during a prolonged shortage of food or how people will assist each other (or not). What will likely happen is in fact deeply rooted in what humanity has always done : people generally tend to move forward, even if it proves difficult.

THE CEREAL QUESTION — RESILIENT OR NON-RESILIENT CROP ?

I had the opportunity to write an article named "UK 1985–1994 : explaining the narrative jump in Threads (1984)" on the movie Threads (1984) and to explain how people survived a decade later without being able to produce cereals on an industrial scale due to the lack of mechanization. The sole explanation for this narrative leap being a shift to root and tuber crops in key agricultural regions across the country. A fictional case that illustrates something critical regarding our modern agricultural systems : despite their qualities, cereals are extremely vulnerable to any forms of severe disruption. The goal of this article is to interrogate the choice being made for decades regarding food security policies, with a clear focus on cereals.

· A fictional movie as a crash test for cereals production
· Cereal, a globalized and technical product, highly vulnerable during crisis
· What we should do to better prepare ourselves
· Conclusion

A fictional movie as a crash test for cereals production

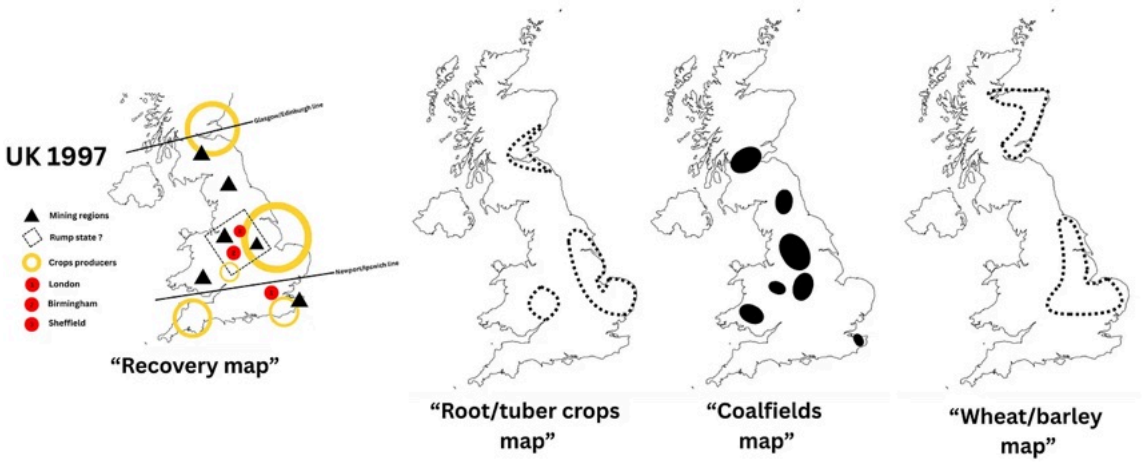
The BBC apocalyptic war drama Threads (1984) discusses the effects of a nuclear exchange on the UK, especially in the surroundings of Sheffield. The most problematic part of the movie is the choice made by the movie to compress the timeline between the first year and a decade later, while providing no explanations on how we can have a functioning society a decade later (coal extraction, education, order…) without providing the necessary basis for these activities : an agricultural system. This is an interesting case in fact because we are in the worst-case scenario regarding agricultural constraints : no fuel, no mechanization, no tractors, no combine harvesters… The perfect fictional crash test for an agricultural system over-reliant on cereals and mechanization.

The United Kingdom was, and still is, a major cereals producer. The movie clearly shows that the whole agriculture is progressively collapsing in the aftermath because of fuel rationing and lack of vehicles. Though, the movie stayed extremely focused on cereals, till the end of the movie. And the movie remains for good reasons (especially to not harm its narrative) silent of what people could have grown and eaten; leaving the possibility that people are still eating mainly cereals. Something implausible in fact and for several reasons.

In nearly all modern countries (and it was already the case in the 1980s), cereal production is now totally industrialized. It means that from the sowing to the harvest, and from milling to food, the whole production is integrated in a complex network of infrastructures, people, vehicles, tools and organization. The truth is that modern cereal production systems are probably the most complex in the world compared to many other crops, especially when produced on mass scale as of today. It requires an enormous amount of resources : fuel, tractors, combine harvesters, milling plants, silos, expertise, processing and ultimately food (bread or whatever). What is going to happen in a scenario like Threads ? Not even discussing the impact of the nuclear winter.

What is going to happen in fact is that the agricultural production of cereals is going to collapse, at least on an industrial scale. Without tractors and combine harvesters, to plow and harvest the large cereal fields of a major cereals producer country like the UK, doing it through manual labour is implausible. Localized and small production remains possible, but not on a national scale, while noting the processing challenges could be huge. Something impossible to achieve and coordinate properly on a national scale without transportation and communications. To explain the movie's biggest mystery, another solution was required. And this solution was : root/tuber/vegetable/legume

crops. This map finally explaining how the movie end scenes are plausible (the crucial missing link between an agricultural system, society and coal production required for the society shown a decade after the attack at the end of the movie) :



Sources :

- *Own work for the **"Recovery map"***
- ***"Root/tuber crops map" :** Agriculture and Horticulture Development Board (AHDB), U.S. Department of Agriculture – Foreign Agricultural Service, "Addressing the land use issues for non-food crops, in response to increasing fuel and energy generation opportunities."*
- ***"Coalfields map" :** Et Margaret Thatcher brisa les syndicats : le Monde Diplomatique (2010), Homes to be heated by warm water from flooded mines : BBC (2020), Northern Mine Research Society*
- ***"Wheat/barley map" :** Agriculture and Horticulture Development Board (AHDB), U.S. Department of Agriculture – Foreign Agricultural Service, "Adverse weather conditions for UK wheat production under climate change"*

I was clear on the requirements for the end scenes "*An agricultural system is required whatever tools are available. The question is not anymore what is the most efficient, but what is available. An agricultural system or nothing. The hoe or starvation*". Hence the obvious shift, at least at the beginning, to root/tuber/vegetable/legume crops. And perhaps, something that totally contradicts the philosophical message of the movie regarding its total-extinction and terminal decline narrative. Even if the process lasted a decade, mass starvation rarely occurs with potatoes, turnips, carrots and other vegetables; while growing some cereals. But that's another story.

And regarding the perfect "plausibility" of this hypothetical scenario, I answered the question both in serious and humorous manner : "*Whether it could have been perfectly true (or not) from a mere agricultural and societal perspective (we have no testimony in history of such a radical shift), doesn't change anything that this reality seems to exist in what is considered the most realistic movie of all time on the topic. It was not contrarian to interrogate its assumptions. Was it plausible ? If so, where and how ? The fact is that it was probably never conceptualised by the filmmakers. But ironically, it emerged naturally from the agricultural and mining landscape of the UK.*

The best and most suited agricultural regions for root/tuber/vegetable crops in the East (especially from East-Anglia to Hull) and coalfields are naturally side by side in this part of the country. If what was on screen should have been true, the map tells us that it would have been not only sensical, but inevitable in the East of England. People and society rebuild with available resources suited to their tools and capabilities. Obvious patterns matter far more than millimetric realities in geographical and human development. Given the geography, you have crucial crops and coal side-by-side. That's all it requires.

Extensive research on every single crops, every single seeds, at every single inch, will lead to the absurdity of complying with the Royal Agricultural Society of England asking me to provide all existing protocols required for my hypothetical post-nuclear 1990s East-Anglia agricultural analysis :

- *Manual carrot seed extraction and storage protocols for non-mechanized agriculture (Volume 6 and Section 9)*
- *Post-Nuclear Hoe-Farming Best Practices Guide (Spring 1995 n°234; communes of Rutland)*
- *Comprehensive Inventory of Post-Nuclear Seed Potatoes: Volume 1 (Norfolk Region)*
- *County-by-county turnip yield projections with soil pH variance tables (Appendix A)*
- *Processing methodologies for hand-extracted sugar under primitive conditions (Section 3.b)*
- *Manual Pest Management for Jerusalem Artichokes in Post-Nuclear Sussex (Volume 9 and 19)*
- *…*

Something that wasn't my responsibility in the first place :)"

But in Threads alternate agricultural universe framework, the joke is not perfect plausibility, it's the idea that for the filmmakers, the most suitable agricultural lands are located in pastoral landscapes known for their lack of soil fertility, poor climate, steep lands and rocks. Whether the East of England is perfectly fit or not for "hoe-farming" is another topic, something that wasn't my responsibility in the first place. The idea was to understand the most logical agricultural patterns.

Discussing root/tuber crops was also interesting because of the Belarus remediation efforts in the 1980s tell us that radiation is not a definitive "agricultural killer"; especially given the Belarus dependence on root/tuber/vegetable crops, something crucial in our fictional context. That's another argument in favor of them to explain why this scenario could have been sensical : "*The Chernobyl disaster affected not only the surrounding of the nuclear power plant but all the surrounding agricultural lands in Belarus, Ukraine and Russia. Belarus' example is telling with nearly 23% of the territory contaminated. Many root/tuber/vegetable products are staple food in these countries. At several times, Belarus produced, for example, more potatoes than wheat. In 1990–1992, Belarus produced a combined volume of root/tuber/vegetable/legume crops totaling 10 million tons, against 7 million tons for cereals. Had the Soviet Union in Belarus, Ukraine and Russia decided to ban all food products in contaminated areas (and not solely the most extremely impacted, as radiation propagates nearly everywhere at different levels across the Soviet Union and Europe), the resulting food crisis would have been far worse than the disaster itself, especially given the state of the food distribution system in the Soviet Union. Like I said earlier, the only solution was to adapt to this new reality. For Belarus : sole ban of the most affected agricultural land (circa 300 000 hectares out of 5 million hectares of arable land, with perhaps 2 million hectares affected initially), crop selection, sole mass discarding of the most problematic products (especially milk, meat, wild food, mushrooms…). Efforts were made to clean the surface of the land. New habits were also introduced like extensive cleaning and peeling of food for example.*"

Why does it matter ? Because given our fictional context, root/tuber/vegetable crops are probably the sole agricultural products you can grow with few tools, people and through manual labor; while still obtaining substantial yields. They don't require a lot of processing and can be eaten quickly. They also hold several advantages : high levels of calories (even if lower than cereals regarding ratio per 100 grams) and nutritional advantages (like the C vitamin, something that cereals don't have, and crucial to stay healthy). The best products for quick production, nutritional needs, storage and processing in a

worst-case scenario : quick collapse of a highly mechanized agricultural system. Something that requires relatively little training for people not accustomed to food production. So, why does this fictional case matter for real-world food security policies ?

Cereal, a globalized and technical product, highly vulnerable during crisis

The fact is that modern cereals have nothing to do anymore with historical production. Centuries ago, everything was extremely local, on a much smaller scale and required relatively simple tools. Now, cereals are globalized from requirements (seeds, fuel, vehicles, fertilizers…), scale (large land areas cultivated), processing (interconnected supply chains) and commercially (national and international market prices). Cereals now constitute a large fraction of daily food intake. Despite their obvious vulnerabilities, many international organizations continue to push for decades in favor of the development of cereals in the least favorable region. Not from a mere climatic and agricultural perspective. But because many countries in the "developing-world" are prone to civil war, political instability and lack of infrastructures. The fact is that the greatest cereals producing countries not only achieve these volumes with the technical requirements but also because of their great stability. You don't harvest million tons of cereals only with fuel, combine harvesters, technical coordination and expertise; but also because of social, political and economic stability. A reality asserted by every major conflict from civil to worldwide ones. Rice is a bit different compared to products like corn/wheat/barley/rye, but rice still requires large coordination. What does it mean ?

It means that in case of any severe disruption, the major risk is that all our food and agricultural production systems collapse because they are over-reliant on a single staple product that even producers themselves will be unable to produce on a more sustainable scale with fewer inputs and tools in the short-term. Some people love to argue that cereals can be grown with animals (horses/cattles) to plough the soil. That's still a liability in case of a major food crisis. What if all (or a large fraction) of animals were eaten ? And even if there are animals, do we still have a plough ? Not one size for large tractors, but for horses. And did our farmers even know how to use it today ? And even if so, the yields and performance are not going to reach those using past technical systems in the short-term. We are still going to need something else.

The straw-man argument regarding cereals during major food crises always begins with this joke : *"Cereals are recommended by the FAO. They have the best caloric density per gram. People are accustomed to cereal based food"…* Sure…*"They are so easy to grow, harvest, dry, transport, process, mill and so on*"…Yes, in our current seamless dreamworld, not in a disrupted one. End of the joke. More concerning, some shift directly to nihilism : "*If there are no cereals we are not going to feed ourselves and others. No matter what we do*". Collapse as a dogma and a religion. Concerning and chilling.

Like I wrote in my agricultural essay on Threads movie, "*I don't romanticize manual labor intensive subsistence farming. [...] But [it is] something inevitable too when you can't use anymore fuel, tractors, combine harvesters and with only few remaining animals. When the only things that remain are hoes, scythes, rakes and people to use them. The fact too is that what we call subsistence farming is also how agriculture originated and something still practiced by millions of people across the world. What we call "Hoe-farming" is far from being primitive : this is in fact basic agricultural history/literacy; especially when nothing else is available."*. I'm not some kind of primitivist who believes in "back-to-soil" ideology. But what I do believe is that if our current agricultural systems

were to be broken, we wouldn't have a lot of alternatives, whatever the tools available. "*The hoe or starvation*" paradigm.

The fact is that feeding ourselves, community or even nation is now something so distant for most people that the only serious model for all institutions is the industrial and large-scale agricultural system. The least resilient one. While asking everyone today to produce its turnips and potatoes is a non-sense (we are not rebuilding a post-nuclear war agricultural system like in our Threads movie analysis), the fact remains that pushing many agricultural communities worldwide toward industrial and globalized agricultural systems is a mistake. Mass abandonment of root/tuber/vegetable/legume crops in favor of cereals ? Sure, but then you have to accept all the constraints : market price fluctuation, fuel and machinery dependency, fertilizers, complex processing systems, only a few harvests seasons… Something that has nothing to do with how these people live, and done in countries with many structural vulnerabilities. Sometimes, the smaller the better. Something that could be improved by simple tools, few fertilizers and better coordination; all these at scalable and community/village level.

Even "us", people not living by the means of subsistence farming, should be concerned by our total disconnection between what we eat and how it grows. Especially for disaster preparedness. To be frank : flat battery, ID cards and a bag with two clothes are not going to be very useful when everything from roads, infrastructures to governance is broken. Even if it looks a bit cartoonish : a hoe and some seeds are going to be far more useful when you are going to need to feed yourself, especially without any supermarkets in sight. As problematic is the belief that a government rationing scheme based generally on cereals, even with good will and care for social cohesion, is going to solve the core problem in the long-term : how we feed ourselves when our food distribution and agricultural production systems collapse because of resource depletions ?

Something, surprisingly, rarely discussed in disaster preparedness. The comforting thought that our past production systems can be restored easily, when we should normally focus on the worst possible outcome : nothing will be like before, hence the need to pivot quickly with sustainable tools and crops.

Some people will argue that root/tuber/vegetable/legume crops are more vulnerable to diseases. Sure. But cereals are vulnerable to resource depletion, mechanization and large scale coordination. All these components are missing in any real-world severe disruption cases : no fuel, no vehicles, no processing plants, no central food distribution systems… And the more you are dependent on industrially produced cereals, the less you have worked on more sustainable crops, the bigger you are at risk of an unmanageable nationwide food distribution and agricultural production breakdown in case of a severe and lasting crisis.

The tragedy that can occur during such a crisis for a cereal, produced on an industrial scale, dependent country ? Struggling to harvest or produce even a small amount on a national scale. And not being able to turn it into food given the complexity involved in modern cereal production systems. To say it in a straightforward manner : starving in front of silos full of grains no one can eat because they are not processed, and perhaps not even harvested.

What we should do to better prepare ourselves

To be clear : no one asks to abandon cereals, a complete nonsense. Like if after criticising cereals monocropping, we decided to shift to root/tuber crops monocropping. In fact, the main concern is that

many modern agricultural systems are not anymore developed to sustain population at sustainable scale : village or “county”/region levels, but generally at national scale level, and sometimes even with a great emphasis on exports. But monocropping of a single product over large areas in entire regions (whether it’s cereals or potatoes) is problematic because in case of severe disruption, it means that entire regions won’t be able to sustain themselves with a diverse food base. What matters : a truly diverse, localized and sustainable agricultural system. And the root/tuber/vegetable crops are important to head into this direction.

The first thing that should interrogate everyone is the commercial and industrial choice of mass monocropping for any cultures on extremely large areas, especially cereals. The choice of abandoning enclosures and more sustainable systems in many countries was done essentially because it was considered inefficient to grow food on small areas not always suitable for vehicles. Common sense ? Not the whole story, especially regarding cereals. The latters matter, but the fact is that root/tuber/vegetables/legume crops largely beat cereals in terms of yields per hectare. On an average in a country like France in 2023 : 40 tons per hectare for potatoes, and barely 8 tons per hectare for wheat. Here is a table on this topic with several others products :

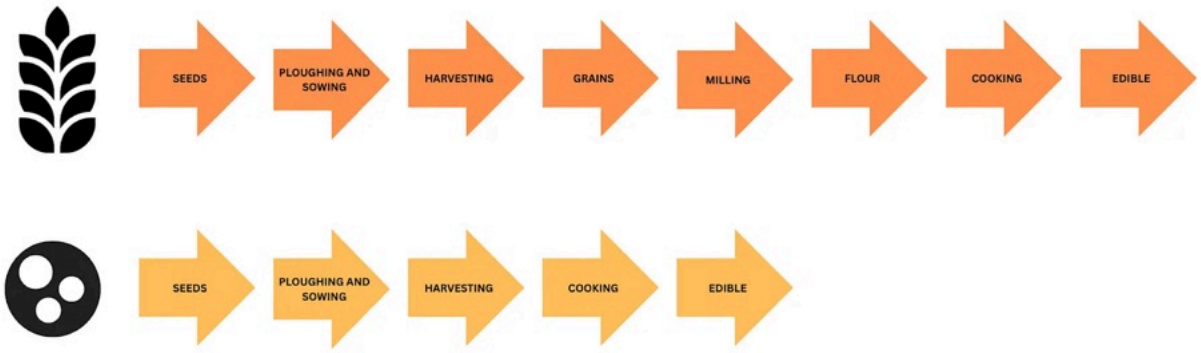
Key figures

Crops	Yield per hectare (tons)
Potatoes	40
Wheat	8
Sugar beet	80
Rye	4
Carrots	44
Turnips	40

Created with Datawrapper

This kind of information should clearly point toward the main issue with cereal monocropping. It has nothing to do with cereal productivity and output. That’s in fact the only way to compensate for its inefficiency against many other products. Something no metrics, whether caloric intake per 100 grams or whatsoever, can compensate for. Worth noting this amount for wheat per hectare is obtained in a country with a highly efficient agricultural system, and a highly mechanized one. Far less is likely expected in less developed countries, in case mechanization is difficult or if the agricultural system faces massive challenges during a nationwide crisis. The “why” a major reflection is clearly required regarding its real value and exact benefits in terms of food security and more importantly, its sustainability in case of major crisis as a sustainable and resilient crop.

The second thing that should interrogate us is our over-reliance on a product involving a lot of steps before being edible : the only things that matter for any agricultural products for a contingency plan, food/agricultural reliefs systems and even crops shift during a major agricultural crisis. To illustrate the point, here is a small scheme to illustrate the production steps required from seeds to an edible product for cereals and most of the root/tuber crops products :



The scheme is telling. In case of a major agricultural crisis, no matter how efficient cereals are, any root/tuber/vegetable crops clearly offer the best sustainability, food availability and quick production that no cereals can't compete with. The steps from seeds to an edible product are extremely compressed. A crucial advantage, especially if we need to quickly fall back on decentralized and hyper-local agricultural production schemes to face severe disruption on a nationwide scale. They are less pretty and glamorous, but far easier/quicker to produce, and more importantly, eat. And that's the key behind these crops : the possibility of sowing, harvesting and processing them on a sustainable scale during a crisis. Something unachievable with cereals : you need lands, vehicles, milling machines and so on.

Third, the time between sowing and harvest are compressed too. For potatoes for example, between 3 to 4 months (90 to 120 days). For winter wheat, you need 8 to 9 months. For spring weather, you need between 5 to 6 months. And for wheat, you still need to follow the long steps to transform grains as edible products. Given climate conditions (something not universal though), some products like turnips and carrots allow for multiple planting times, offering the possibility of multiple "small harvests". These products are clearly critical in case of severe disruption.

Set apart the specific crops we want to grow/store in case of severe disruption or simply because we want a more sustainable agricultural system, we also should care for tools and/or machinery to produce and harvest them. Like I said earlier : are we able to face a major case of de-mechanization of food production because we lack fuel or national coordination ? Because we should care for seeds, we should also care for tools. Whether it is hoes, "lighter" forms of ards or ploughs we can use with animals; we also need to think for them. It should be part of any serious contingency plan.

Conclusion

Exploring the possible agricultural system in Threads (1984) following the collapse of mechanized agriculture opened my eyes to topics overlooked both in fictional movies but also in public discussion on agricultural sustainability. The basic : we need an agricultural system, whether it is with the hoe or the tractor, producing potatoes or wheat. The problem : what happens to any agricultural system facing severe disruption ? Exploring the hypothetical post-nuclear war UK agricultural system was very interesting : finding the best match between crops, available methods, lands and coal mines to provide the glue for the end scenes of the movie. A pivot I found difficult to achieve, because I was

wired like everyone to think as a “cereal producer”, despite acknowledging all the constraints. Something also telling on how deep is entrenched the culture of cereals in our mind. And on the vulnerability of any cereal producing countries.

In the alternate Threads universe : we have invested so much land to produce cereals, impossible to produce/harvest without mechanization, that what remains is a fragmented and hyper-local agricultural system as depicted with my map. Several areas here and here, but not the same agricultural continuity as with cereals.

Something that motivated me to write this article. Even if fictional, and because the movie left the topic unexplored, it was important (and even required) to imagine the continuity of an agricultural system. Especially by imaging the best crops suitable to our precarious conditions. If we can discuss and imagine that in a fictional universe, even if it’s on paper of course, why not in reality ?

I think this work was some kind of a revelation for me : we are taking for granted and natural things that definitively are not. Producing cereals, like root/tuber/vegetable/legume crops, is important of course. But what amount ? With what kind of tools and process ? The truth is that what is sold as a dream (infinite fields full of wheat/barley/rye) can quickly turn into a nightmare following any major disruption. How are we going to sow these infinite fields with no tractors ? Harvest them without a combine harvester ? And even if harvested, how are we going to turn these cereals into something we can eat if we can’t process or transport them ?

The natural path for many countries should be to accept that a more sustainable and better mix of crops is in fact what makes any agricultural system far more resilient. What is the meaning of producing nonsensical amounts of food if we are forced every year to export them or give it to the livestock ?

The fact is that cereal is not anymore the standard symbol of agriculture. Nor the symbol of civilization as it used to be. This is now a mere commodity whose size in many agricultural systems for mere commercial profits (especially exports) is making them non-resilient in face of any disruption (international, national, regional…). You can’t have both : millions of hectares allocated to them, millions of tons of cereals produced every year that people and livestock can barely eat, without doing it at the expense of the land and crop diversity. And more importantly : at the expense of agriculture and people’s resilience. The worst thing that could occur is not lacking cereals because of a severe disruption, it’s lacking any food because of past choices disconnecting the agricultural system from its ultimate goal (something that can occur with nearly all food products, when their production is disconnected from local realities).

Feeding people. On a sustainable and meaningful scale. With a diverse agricultural landscape. And resilient crops…*Quod sunt potatoes, dolor sit amet, portique…* instead of…*Fiat panis*

THE KHMER ROUGE — WHAT DOES IT MEAN FOR THEM TO BUILD A "PURE SOCIETY" IN ITS PRIMEVAL FORM ?

Disclaimer :
The essay you are going to read is totally subjective and speculative. We do not assume to hold the truth on this complex topic, what we want is to understand through a different lens what could have happened in the mind of the Khmer Rouge for such atrocities to occur. What we have tried here is some sort of speculative retro-engineering of their mindset based on what occurred in Democratic Kampuchea, and not what was claimed by them years and decades later. This essay is not intended to provide a comprehensive historiographical analysis, nor to compete with scholarly research grounded in archival work. Rather, it is an exercise in interpretive reasoning—a phenomenological and psychological exploration of how such a worldview could take shape. Any conclusions drawn should be understood as reflective and tentative, not definitive.

When we look back at history, many human tragedies like the Great Leap Forward, the Holocaust and the Holodomor can be explained in a way or another, and are not beyond the scope of human comprehension. The Democratic Kampuchea genocide, on the contrary, is something that most of us have difficulties to process. How could a country and its leadership have decided that their "problem" was not with a specific minority, some isolated regions or even a foreign country; but with nearly its whole population ? This is the goal of this essay : reconstruct from the Khmer Rouge perspective what led them to organize this genocide.

The major difficulty faced by historians and researchers on this topic, is that the documents from this period are relatively scarce. For example, contrary to the Holocaust or the Holodomor, we don't have any pictures or footage directly made by people in Democratic Kampuchea to assess the scale of the violence and how the daily life was; apart from a few propaganda films made by the Khmer Rouge, testimonies by survivors themselves and some drawings made by survivors too. An issue similar to what happens when we want to analyse the Great Leap Forward in China. Another issue is that the Democratic Kampuchea and the Khmer Rouge leadership lived for 4 years in near-complete isolation from the outside world, and very few (if none) documents exist to explain the rationale (if there is one) behind the genocide. How could we explain the "irationale" nature of the genocide (from an outsider perspective) ? The fact is that few answers are available in reports, propaganda leaflets or interrogation documents. These documents seem good to explain the outcomes, the life within Democratic Kampucha, but not the root cause of the genocide.

What is proposed here is to build a tentative and speculative reconstruction of how the Khmer Rouge leadership mind was shaped and what could have been their ideological motivations, based on what they do and the outcomes of their choices—and not what they said, either themselves or through propaganda documents.

As a reminder, the Khmer rouge genocide is still controversial up to date. Historians and researchers were criticized in the past regarding their attempts to formalise the genocidal process with the "individual/collection actions" framework or the "mandala theory". Many others works were written developing alternatives theoreis like foreign involvement in the genocide. The issue is controversial because in the 1970s, many people in the intellectual world were prone to condemn what was described as the "American Imperialism" in Southeast Asia, notably during the Vietnam war. The topic was sensitive as some intellectuals were prone (before the collapse of the Democratic Kampuchea) to praise the Khmer Rouge. A situation difficult to reconcile with the extent of the genocide discovered after 1979, leading to the creation of the "Standard Total Academic View on

Cambodia" concept regarding the difficulties for many people involved in academic research on the topic to reconcile or admit their mistake regarding the Democratic Kampuchea.

The historical background

Cambodia has a long and troubled history before the establishment of the Democratic Kampuchea. It was a French colony between 1863 and 1953 under the name "French protectorate of Cambodia" (In French : "*Protectorat Français du Cambodge*"). Contrary to what occurred during the Algerian War of Independence (a long and deadly war of independence lasting 8 years, and leading to the independence of Algeria from France), France accepted to put in place a progressive transfer of sovereignty to the king Norodom Sihanouk.

The process, even if imperfect, should have been relatively smooth. Unfortunately, this was without accounting for the troubled context of the surrounding countries. China established itself as a communist country in 1949. The Vietnam war started in 1955 and ended in 1977 with the victory of the communists under Ho Chi Minh leadership. Internally, the hope surrounding independence faded progressively as Sihanouk (despite being respected as a monarch) demonstrated authoritarianism, corruption and failed to put in action a comprehensive program for the development of the country. The situation escalated with a coup d'etat and ousting of Sihanouk in 1970 by Lon Nol, abolishment of the monarchy and the establishment of the Khmer Republic backed by the United States. The regime won't fare better, and will not survive more than 5 years of a deadly civil war leading ultimately to the fall on Phnom Penh on 17 April 1975 at the end of the Khmer Rouge.

Norodom Sihanouk (Rob Croes for Anefo, CC0, via Wikimedia Common)

The "Paris club" and the emergence of a "pure society" vision

The formation and the development of the Khmer Rouge leadership base and ideology had little to do at the beginning with a strong anchor in Cambodia realities. The process was in fact parallel and intertwined with the country's history between 1953 and 1977. The historical founders of the Khmer Rouge (Pol Pot, Hou Yuon, Ieng Sary…) also had little to do with the Cambodian agrarian world as

most of them were highly educated and city dwellers. Pol Pot and Ieng Sary were both students in the 1950s in Paris for example. They even traveled in East Germany. So basically, their initial life demonstrates no disdain for “city life”, nor a willingness to return to a rural society like they will do in their later life.

The process behind the Khmer Rouge ideological framework seems to have little to do with Mao teachings too. The self-reliance vision developed by Mao had nothing to do with the abandonment of cities, but with a strong will to transform China (sometimes described as a “colony-country” before 1949) into an independent and strong country accounting for its local challenges. The fact that Mao made many dangerous decisions for the Chinese people, like pushing some reforms too quickly with the Great Leap Forward causing the death of many people, still has nothing to do with the extent of what happened in Democratic Kampuchea. The sole thing that could tie the Khmer Rouge policy in Democratic Kampuchea is the fact that many choices were implemented in a hurry.

The process, in fact, seems to have more to do with something close to what we can describe as a sectarian view of the world. Something clearly tied to the puzzling willingness of the Khmer leadership to push in favor of an agrarian utopian dream at all costs. Like if going back to the countryside will magically erase all the issues of Cambodia. When the core of the historic Khmer Rouge leadership decided to move back to Cambodia to push for their revolutionary idea; they progressively decided to move to a guerilla style program (something common to many communist movements across the world). Like the Viet Cong, they hid themselves in the countryside. And more especially in the mountainous region of Cambodia, in the Ratanakiri province. They were close to the Khmer Loeu, a very small people within Cambodia living in temporary small villages. Contrary to Karl Marx expectations, many countries who witnessed communist revolutions were not highly industrialized.

Did something happen in this mountainous region ? Educated people, having lived in cities for years, don’t suddenly transform themselves into agrarian utopists out of nowhere. People who studied at the university, had a fascination for France, walked in the streets, drank in a coffee, went to the theater or cinema, probably looked at women in the street… don’t transform themselves out of nowhere into agrarian utopists with such a disdain for modern life. It was natural in many South-East Asian countries for revolutionaries to hide in the countryside and be close to the peasants. But the peasantry was always a means, not an end. The latter was the case for the Khmer Rouge. Did the original motto of the Khmer Rouge, which was probably very similar to other communists movements, shifted progressively to : “The future of our country has nothing to do with factories and societal progress; it has to do with being like these Cambodian country men and women : living in simplicity and in a communal manner; preserved from external influences” ? The life of the “innocent” Cambodian men and women from the countryside was of course more complex than that, but from what we know of the Democratic Kampuchea, nuance and reality completely faltered over time.

Is it totally true ? The fact remains that the countryside and rural world is generally associated with “positive” values : humility, community, hard work, simplicity…. It’s difficult to quantify what happened exactly in the mind of the Khmer Rouge leadership (it’s even possible that themselves will never be able to quantify it), but given how the movements grew in Cambodia and how far they were willing to go regarding their agrarian utopia, their ideology shifted progressively from the core of communist ideology (fraternity, hope for a new world, industrial development, modernity…) into a practical program to reach their new dream of a “pure society” (a rural, modest, hard-working… society) in its primeval form. A world where cities, money and the old social fabric should disappear

to form an agrarian utopia where violence, immorality and old hierarchy should disappeared; in order for a “pure world” to emerge. From my perspective, all these things form the very core of the “us” and “them” of their ideology. Worth noting also that the Cambodian civil war, leading to the overthrow of the Khmer Republic, lasted for 8 years. This is a long time, especially considering that the Khmer Rouge apparatus mostly spent time with rural people, something normal and logical given the nature of their guerilla, but completely losing sight of the point of view of urban people (which were not part of the Khmer Rouge take over in fact). In the Soviet Union for example, the communist leadership had a solid stronghold in cities at the time of the Revolution but struggled a lot with the countryside. The contrary occurred in Cambodia : they were well implemented in the countryside, and pushed their country into a complete rural utopia.

Cambodian Civil war (Department of Defense, Public domain, via Wikimedia Commons)

Apart from their nearly sectarian point of view, their decisions were perhaps also influenced by what was done by governments in and around Cambodia. The corruption of many US-backed governments was obvious for everyone. It could have comforted their worldview that the “old and continuous” structures of the world were inherently bad and cannot be salvaged by any means. A new world was needed. A world where Cambodia will revert back to an hypothetical mix of “agrarian utopia” and “Angkorian” golden age. Something ironic : a group of agrarian communists was hoping to revive an old imperialist empire… switching back to an “agrarian utopia” and monoculture economic model. Their “Angkorian” component proves that we were not anymore dealing with communists in the traditional sense of the word but with people developing their very own ideological, political and economic project.

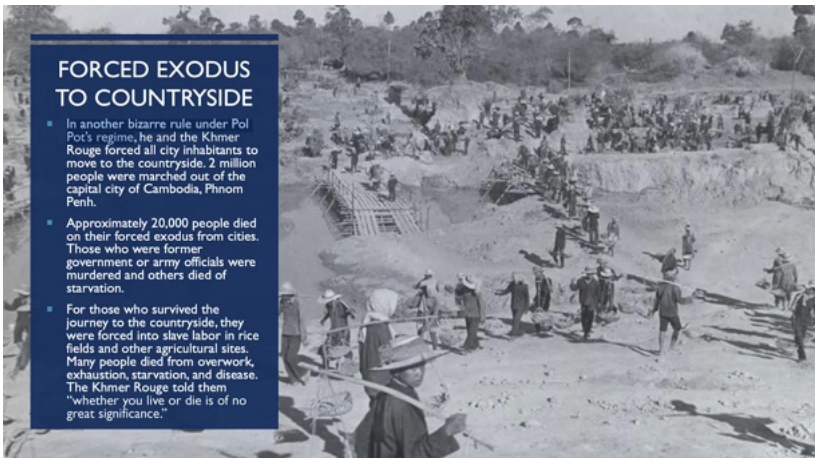
Another factor that could have influenced the complete disjunction between their vision and what happened on the field is that many of the top Khmer Rouge officials were highly educated people : Pol Pot, Khieu Samphan and Kang Ke Kew… All these men were objectively educators and intellectuals in fact. Contrary to other countries where many revolutionaries were people from lower-status. Something ironic when we knew that the first people targeted during the Democratic Kampuchea genocide were the “intellectuals” (sometimes named the “glass-wearers”). Should this move be interpreted as : “We were wrong, but we have learnt from our mistake after spending time with the “true” Cambodians (the rural one), so the others should too” ? A form of self-hatred turned against the other ? We know no past genocides where people planning it were similar (from an ethnic, religious and societal perspective) to their targeted victims. While this kind of explanation requires

caution, it's interesting to discuss it as part of a broader issue and specific worldview within the Khmer Rouge leadership.

To conclude, and this time from my personal perspective, the collapse of many of these US-backed governments in this part of the world during the 1960s-1970s has little to do with the US bombardments in Cambodia and elsewhere. The fact is that bombs don't convince or change people, and only slow down an inevitable process in history : people want to feel at home with accountable governments, and being respected for what they are; and not being told to adapt to the standards of abstract and distant countries, especially when these "standards" are enforced by corrupt and inefficient governments.

1975–1979 : the "Year zero" and building the "pure society"

When the Khmer Rouge took Phnom Penh in April 1975 and decided to evacuate cities, we shouldn't accept it to be described as a "bizarre" plan. It only had to do with a clear and formal project to reshape the society. On this topic, the Illinois Holocaust Museum and Education Center presents what happened as this : "I*n another bizarre rule under Pol Pot's regime, he and the Khmer Rouge forced all city inhabitants to move to the countryside. 2 million people were marched out of the capital city of Cambodia, Phnom Penh*.".



Excerpt from the brochure "THE CAMBODIAN GENOCIDE ORIGINS, GENOCIDE, AND AFTERMATH" by the Illinois Holocaust Museum and Education Center

This statement is dangerous. There is nothing "bizarre" in what happened : no randomness, no miscalculations, no misunderstanding… As explained earlier, the Khmer Rouge were probably far from being simply driven by a basic hatred of the modern world. Could they have sincerely believed in their dream of a totally transformed society ? And what does it mean ? The fact is that from what occurred in Democratic Kampuchea, we can deduce that from a Khmer Rouge perspective, the people in cities were not just living in the wrong place, simply meaning we should relocate them. Neither it has to do with an economic shift toward agriculture (because it probably had nothing to do with the economy in the first place). It could have been far more important : these people living in cities were probably not only "inherently wrong" as demonstrated by the Khmer Rouge attitude later, they were assimilated to the very "incarnation" of what society should never have become in the first place for the Khmer Rouge.

Democratic Kampuchea administrative regions (Library of Congress. Federal Research Division., Public domain, via Wikimedia Commons)

When we accept this possibility, we can try to understand and reconstruct the logic leading to the mass exodus from cities to the countryside. From my perspective, it has nothing to do with chaos or disorganization. From the Khmer Rouge perspective, it was probably the beginning of their utopia. The first step to erase the past was easily achievable with the most basic and less costly solution possible : forcing people to move with their feet to the countryside. Anyone would have perfectly acknowledged that many people were going to die, especially the disabled, the sick and the very old. When people in cities were suddenly asked to leave everything behind them and were forced to walk for miles, they were also extremely vulnerable. This brutal event with no transition allowed the Khmer Rouge to fulfill their primary goal, by removing from the equation the very “core” of why human society was inherently immoral : cities.

Flag of the Democratic Kampuchea

Some historians and researchers argue that the process was chaotic and not planned because some accommodations were provided sometimes for elderly and some sick people. Rumors about bombings existed too. The only thing it proves unfortunately is that some of the people ensuring the emptying of cities were aware—in a way or another—of what it means for the weak people to walk with nothing to the countryside. Meaning in turn that these people hold even more responsibilities in what occurred, because they had the intellectual and moral capacity to process—something the sincere "agrarian utopia" believers had possibly lost—what was occurring, and should have acted to stop it. Some people argue that some statements point toward chaos and high disorganisation. Let's explore some of them made by the Khmer Rouge themselves :

- "*[Phnom-Penh which] Cambodian peasants regarded as a satellite of foreigners, first French, and then American, and which has been built with their sweat without bringing them anything in exchange.*"
- "*[The Khmer Rouge] didn't have any transportation facilities to bring food to the people, and so the logical thing was to bring the people to the food, i.e., to evacuate them all and make them get out into the ricefields.*"

Even if the reasons given differ : the result is the same. The first statement is relatively honest about the Khmer Rouge views on the cities. The second is some of an attempt to rationalize the process, while providing the same result : moving urban dwellers to the countryside. None of them disprove the willingness of the Khmer Rouge to fulfill their plan at all cost. This is the perfect example of the real danger of taking at "face value" statements made by the Khmer Rouge, and trying to resonate with them as if these statements were proof of a reality. From an historical perspective (and for the Khmer Rouge) : cities were an anomaly in a world that was historically a rural one. An "unnatural "product leading to the corruption of human beings ?

When people settled in the countryside, the Khmer Rouge were willing to move to the next step of their project : building a rural society with no class. The new divide was between "new people" (those from cities) and "old people" (traditional peasants). What does it mean ? When many communist countries dreamed of building a "new man" (Like the "Homo sovieticus"), the Khmer Rouge thought that a "rollback" was needed in fact. It means that they were not going to "build" but to "deconstruct" people.

Ceausescu and his wife meeting with Pol Pot

It was like saying to them : "For decades and centuries, you thought you were writing the future of history and society by building big cities with bricks and complex social fabric; but you were wrong,

the future lies in these simple men and women from the countryside who were left untouched by modernity".

The "new people" inevitably became forced laborers and were the first targeted by violence, apart from some of them who were back in their birth village and assimilated to the "old people". While the topic is taboo, some of the "old people" were sympathetic to the Khmer Rouge as they had a lot of resentment for people from the cities too, even if it had nothing to do with the ideological project of the Khmer Rouge. Unfortunately : such a brutal regime doesn't survive alone. It survives because many people adhere to its ideas, either by sympathy or fear. Even though it's an uncomfortable truth for people, we should acknowledge that the Democratic Kampuchea had plenty of supporters within its own people. Pre-Democratic Kampuchea society was indeed not an equal one, but this shift transformed it into a completely unequal and inhumane one, where the "new people" were denied any capacity, worth and value.

A woman and her baby at Tuol Sleng jail (Unknown Khmer Rouge photographer., Public domain, via Wikimedia Commons)

Worth noting, the Khmer Rouge made an important move when taking over the country and starting the "agrarian utopia" : the leadership went "faceless" till 1977 (two years after the overthrow of the Khmer Republic, and two years before the fall). What many people knew of the Khmer Rouge during the Democratic Kampuchea was through a mysterious organization named the "Angkar" (A Khmer word roughly translated as "*organization*"). All previous revolutions in history had always seen their leaders exposing both themselves and their political stances. This situation aligns with a leadership for whom belief, fear and control matter more than communication, politics and "being human" (in the sense of being relatable to people, as a public personality could be). The Cambodians were probably clueless when faced with something being so abstract and non-relatable. The threat could have been both "impalpable" and "omnipotent". This level of reclusion and secrecy probably fostered the isolation from the fields by cutting the Khmer Rouge leadership from reality, contradiction and ultimately their own people; comforting them in their sectarian worldview. It probably creates a perverse effect too where people on the field receiving orders felt less liable of the consequences and could have taken dangerous initiatives, as the whole hierarchy was obscure. But as explained : these are the consequences, not the cause.

When people and their social fabric are designated as “inherently wrong” for decades and centuries, a new one is needed. Khmer Rouge possibly drew their inspiration in their belief that many rural communities were more tight-knit than urban communities; something more complex in fact, but in the Khmer Rouge ideology, nuance didn’t exist.

But the project put in place for the “new people” had nothing to do with a “communal” one. What was needed was to destroy all of the past social fabric. Why are families and couples a problem ? They exist in rural communities too. The very fact is that the Khmer Rouge were willing to build an utopia where all social stratas (family, friendship, couple…) were required to disappear or to be transformed in a way acceptable for the Khmer Rouge. Why ? Because families, friendships and couples formed by the “new people” allow for the continuation of their past lives, friendships and solidarities even in a diminished form. Also because it creates a coping mechanism when the Khmer Rouge people only saw two paths for the “new people” : disappearance or death. They went as far as “erasing” the simple solidarities that existed between people (like a mother caring for her child, two young boys being friends, a loving couple…) by splitting and mixing everyone into abstract and impersonal brigades; making everyone vulnerable with the collapse of all forms of solidarity.

It’s not unlikely that the Khmer Rouge leadership was projecting its self-hatred onto its own people, especially the urban dwellers : “we were wrong, we have learnt, you have too”. This kind of situation naturally arises when people, rather than respecting ingenuity or difference in human societies, come to the problematic conclusion that the different people they genuinely love are better than them. Meaning in turn that differences can’t coexist. Khmer Rouge rouge were educated and literate people. City dwellers too. There is nothing wrong in respecting rural people for what they are and appreciating their way of life. What is wrong is when people start to denigrate the core of what they are to align with what they love. When people became foreigners to their own identity, and when enculturation began.

When a whole political apparatus decides that everything they had loved and appreciated should be erased to fulfill their dream (without any compromise), it can only lead to a complete denial of reality, and then to human suffering. Even more when there is absolutely no room for compromise.

The next, and unavoidable step, was the physical elimination of the “new people” who were products of modern societies : intellectuals, scientists, lawyers, teachers, “glasses-wearers” (a cruel stereotype associating glasses and intellectualism)… Why kill people who could have been helpful to sustain the new “agrarian utopia” ? The Khmer Rouge were not materialistic but clearly sectarian in their beliefs; it has nothing to do with realism, pragmatism and sustainability, but with building an utopia and fulfilling their dream of reverting to a primeval world. Whether these people could have helped the Khmer Rouge to fulfill their dream was of little importance. Killing these people had probably a lot to do with their minds and what they represented. People can give the appearance of compliance and think otherwise. Even when compliant, people from a specific intellectual background tend inevitably to reproduce this background. Even if we put a hoe in the hand of a doctor, and tell him to work the whole day in a rice field, the fact is that at one point or another, this person is likely going to be a doctor again. It could have been—like in so many totalitarian regimes—the biggest and most existential threat for the Khmer Rouge : the possibility of a slow but noticeable return and continuity of this “pre-utopia” world; meaning the destruction of their utopia from the inside in the long term.

The Khmer Rouge targeted ethnic minorities too : Vietnamese, Chinese, Thai and Muslims… When you have people coming from different backgrounds (intellectual, social, religious or ethnic) you have

also to build a shared narrative for everyone. The erasure of any difference (economical, ethnic, religious, intellectual…) eases the process, especially when you rely on the primal instinct of people to reach your goal : racism, prejudices and inferiority complex. Even the Buddhist monks, who followed the Buddhist precepts (abstaining from taking life, taking what is not given, from sexual misconduct, from false speech…) that could have aligned with the Khmer Rouge fight against immorality were targeted too. No alternative narrative could have coexisted in Democratic Kampuchea.

Khmer Rouge leadership (Nem Sopheak Panha, Public domain, via Wikimedia Commons)

The fulfilment of their worldview implied for the Khmer Rouge the disappearance of all symbols characterising modern economies : money, trade and industry. Bartering was the only way to exchange goods within the country. With the move to the countryside and the abandonment of the industrial infrastructures : little to no medication was available for people, tools and other goods were scarce… The school system was hampered and nearly disappeared. Nearly all hospitals were closed. But at one point, reality hit back. And ultimately, the Khmer Rouge were forced to re-open factories outside abandoned cities and move some of them to the countryside.

Some researchers and historians argue that the main cause of the Cambodian genocide was something like of a “death pyramid” system, where unrealistic production goals set by the Khmer Rouge leadership lead to mass deaths; as all the people across the “pyramid” were unable to met the quotas and turn violent against each other, and finally against the Cambodian people. Historians and researchers have attempted to exploit propaganda leaflets to understand the goals and results of the Khmer Rouge policies. For example this statement by Ieng Sary (deputy premier) : “*[The regime is] pursuing radical transformation of the country, with agriculture as the base. With revenues from agriculture we are building an industry which is to serve the development of agriculture*.”. If we take this statement at face value : the Democratic Kampuchea was making a rational choice to focus on agricultural production and rebuild an industrial base. The reality ? None of them occurred. We can’t even speak of “restarting factories” because of how marginal these efforts were.

Many other signs clearly proved the dichotomy that occurred with the Khmer Rouge leadership. Democratic Kampuchea was able at some points to export rice. Does it prove that the regime was aligned with China and Vietnam ? It probably has nothing to do with that. It’s simply a common shared strait by many “utopian” regimes willing to save the appearance of abundance; and also trying to secure foreign currencies or goods through bartering. A fact proving the complete dichotomy

imposed by the Khmer Leadership and a landmark of how the regime works : displaying a sense of normalcy outside while doing something completely abnormal on the inside (at least from an outsider perspective); the two faces of the same country.

Tuol Sleng prisoners mugshots (Jws Lubbock, CC BY-SA 4.0, via Wikimedia Commons)

The death estimates are generally around ¼ of the Cambodian population killed by the Khmer Rouge. When you look at pictures and footage made in the year after the fall of the Democratic Kampuchea, there were literary bones everywhere in the country : from village outskirts to nearly every single field. Penal camps (like the infamous Tuol Sleng) existed but were not the absolute norm (contrary to the Holocaust or the Gulag system). Contrary to other historical genocides, the major acts of violence were not happening in remote camps, but near the place of living of people. Several reasons can explain this choice. The first one is that resources were scarce in Democratic Kampuchea given the complete economic isolation of the country. It was not possible to move people by train or trucks to remote locations; given fuel scarcity and because infrastructures were in disarray, and only used on a small scale and out of necessity. The easiest way to do that was to designate “killing fields” across the country where people could be conducted and executed more easily. The second was probably less for deterrence and more because the Khmer Rouge, given their ideology, didn’t have anymore the moral and psychological barriers that generally prevent people from showing the extent of their crime to everyone. Nazis and even the Soviet Union put a lot of work into hiding things : mass graves, destruction of gas chambers, burning of records, remote locations for camps… Not the Khmer Rouge who left bones and bodies scattered around the country.

Doing it in sight of everyone was possibly perfectly normal if it was at the cost of fulfilling their worldview. Killing people in their familiar area, *en masse* and in front of everyone, could have been a complete and natural part for the fulfillment of this project. We can barely imagine the despair and terror of these innocent people conducted by night or day to these locations, seeing possibly all these dead bodies and bones, and perfectly understanding what it meant for them; contrary to the perverse organization in past extermination camps where prisoners couldn’t immediately realize their fate.

Skulls found in the “Killing Fields” (Dr. Hubertus Knabe, CC BY-SA 4.0, via Wikimedia Commons)

The genocide (in the sense of organizing the killing of people on a mass scale) was probably not even carefully planned like the Holocaust or the Gulag system at the beginning. It became the inevitable end-point (rather than a pre-planned goal) of a sectarian belief system where all moral barriers disappeared in the head of the Khmer Rouge, because the immediate results (mass deaths, starvation, suffering…) holds no value compared to the “greater dream”; especially when the rationale at the time was between the “us” and “them”, an existential struggle between “pure” and “impure”. The first murder was probably an exhausted person on the road during the evacuation of cities for being too slow and being suspected of escaping the “great march”, leading in turn to an unstoppable escalation as a “justified” murder of an innocent is necessarily a call for another : the ex-representatives of the defunct Khmer Republic spotted amid the refugees, then the intellectuals and “glasses-wearers” in the fields and ultimately everyone by every means (starvation, hunger, torture, executions…)

What is extremely impressive is the gap between the agrarian utopia cherished by the Khmer Rouge and the agricultural realities at the time. Basically, the Khmer Rouge were unable to organize any form of agriculture and fed their own people (the “new people” like the “old people”). Working in the field is not something everyone can do. People don’t magically become farmers because you “dream” of it. Starvation, death and diseases were rampant everywhere. All these failures could only have fostered their violence and led to a growing paranoia at every level in the country, from children spying on their parents and internal feud within the leadership.

Typical Khmer Rouge dresses (Toony, CC BY-SA 3.0, via Wikimedia Commons)

Like the Soviet Union during the collectivization campaign or China during the Great Leap Forward, the Khmer Rouge resorted to propaganda about the people discovering new methods; and agricultural output improving.

While discussing the Khmer Rouge leadership mindset, what were the motivations for the simple executioners ? Like in many past genocides, “low-status” executioners tend to rationalize their motives : we have received orders, doing otherwise was impossible, we saw nothing, we were illiterate… Regarding the Democratic Kampuchea genocide, it’s worth noting that many executioners where illiterate young men from the countryside. But I don’t believe in radicalization out of nowhere. The fact is that these people were likely allowed to translate their long hatred and willingness for revenge against urban people into mass murder under the blessing of the Khmer Rouge officials.

Regarding the peculiar cases of educated people like the infamous “comrade Duch” who were conducting operations on the field, they are perhaps the most “unsettling” incarnation of all these zealous people that do what they are told to (from “tightnight bolts” to genocide) with a sense of detachment and compliance that leaves us baffled. But the fact is that these people perfectly knew what they were doing, as his escape from the country and his return under a false identity proves it. Contrary to the young men killing people in the “killing fields” who can be—in a very limited way—pardoned for being illiterate and for being young; these people have no excuse. Comrade Duch was not coming out of nowhere. He joined the maquis too with the other Khmer Rouge officials; and his first work for them was as a prison commandment. He likely shared their “greater dream” and was one the best at this job. He had the opportunity (and even the moral and intellectual capacities) to leave every time, but chose to stay.

The “Angkorian revival” dream and the demise of the Khmer Rouge

The Khmer Rouge, people dreaming of a pure and new society with no class barriers, corruption, violence and immorality, replaced with fraternity, kindness and simple people living/working in fields; ended up killing their own population on a massive and unprecedented scale. Probably for the simple reason that they saw their own people as part of the problem, and not as part of the solution. They destroyed the social fabric of the country, its industry and infrastructures, and also all the things and people who could have allowed for a brighter future. Given their communist stance and the fact they were surrounded by communist countries, there was no threat to justify the brutality of the regime. The country could also have followed a development model with a clear emphasis on agriculture (like the “green revolution” in India) if it was their dream. In fact, the dream became a nightmare for everyone, and even agriculture was in disarray.

The cause of their demise, ironically, has nothing to do with food shortages and starvation, but only with their grandiose dream of restoring the great and mythical “Angkorian kingdom”. This movie led to a war with Vietnam, and finally the invasion of Democratic Kampuchea and the fall of the Khmer Rouge. We can’t understand this kind of “grandiosity” if we don’t understand what they were. It has nothing to do with the careful planning of the Barbarossa Operation for example. But probably only with people clearly living in their own world, at the expense of their own people. This old kingdom vanished somewhere around 1431. At the beginning, the Vietnamese tried to resonate with the Khmer Rouge officials by working on a settlement on the border dispute. But how to work with people planning to rebuild a millennia-deceased empire while living in total denial of the utter failure of their “greater dream” ? The fact is that the restoration of the Angkorian Empire could have been the last and natural extent of their vision : restoring an historical kingdom known as a major agricultural

center, focused heavily on rice farming. A barely urbanized kingdom compared to other civilizations. The realisation of their “dream” on a bigger scale. And perhaps ironically, an old and idealized kingdom that suffers the same fate as the Democratic Kampuchea, and nearly for the same reasons. A demise under the pressure of many compounding factors : diseases, agricultural and ecological breakdown, external pressure… Something the Khmer Rouge should have known and studied in the first place.

One of the final acts of the regime was the Eastern Zone massacres in 1978; where the only solution found by the Khmer Rouge was to exterminate their own cadres. At the end, what remains of their dream, their sole legacy, are the “killing fields” and bones. A war raged for decades between the remnants of the Khmer Rouge and the new Cambodian state from 1979 to 1998.

Conclusions

What could have been done to stop the Khmer Rouge genocide ? Not so much unfortunately once the process was started. The society was so disorganized, brutalized and under control that very few things could have been from the inside. Perhaps, the regime could have collapsed under the burden of an inefficient agricultural system. Or an internal feud within the Khmer Rouge leadership. Fortunately for the Cambodians, it was the mistake done regarding the Cambodian-Vietnamese border that ultimately led to the demise of the Democratic Kampuchea.

What we have reflect upon here was uncomfortable both for us and for the reader : the idea that even the most controversial and un-understandable genocide was not a mistake or the result of poor logistical choices, but the unfortunate and logical outcome of a completely distorted worldview. Whether our discussion is perfectly true or not : the fact is that the Cambodian genocide shouldn’t be anymore defined by “bizzare rule” or by blindly reading Khmer rouge leaflets and propaganda video. Neither should we accept the way the genocide was downplayed in several academic circles, especially leftists one (eg. Noam Chomsky and his Nation article).