Evaluation and Prediction of the Future Development of Nuclear Weapons in the World Based on AHP and Neural Network

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Abstract. This paper first establishes a BP neural network model based on the steepest descent method to predict the number of nuclear weapon states in the next 100 years. Combining the AHP analytic hierarchy process model, it predicts the countries most likely to possess nuclear weapons in the next 100 years. Then, a linear regression method is used to predict the total number of nuclear weapons in 2123. Then calculate the killing range of nuclear weapons and establish an explosion location model. Finally, a model is established using cellular automata to determine the minimum number of nuclear weapons required to destroy the human survival environment, and to derive the limit range of the number of nuclear weapons. Finally, we describe our research results and propose some suggestions for the common destiny of all mankind.

Keywords: Development of nuclear weapons; AHP; BP neural network; Cellular automata; TOPSIS.

1. Introduction

In July 1945, the "Manhattan Project" team led by Oppenheimer successfully developed the world's first atomic bomb, entering the nuclear era. On August 6th and 9th of the same year, the United States dropped two atomic bombs, "Little Boy" and "Fat Boy", on Hiroshima and Nagasaki, respectively. The power of 20000 tons of TNT equivalent has brought a devastating blow to these two cities. The power of this nuclear attack shocked the world. Countries have begun to recognize the power of nuclear weapons, which can be called the god of destruction in strategic weapons. At the same time, nuclear weapons have also become an important indicator of national status and strength in the future international political arena, and nuclear deterrence has also become the trump card in handling international affairs in the future [1].

The latest research report from the Stockholm International Peace Research Institute shows that there are currently about 15850 nuclear warheads worldwide, of which the United States and Russia have 14760, accounting for 93% of the global total. Overall, the world's major nuclear powers still regard nuclear weapons as the strategic cornerstone for maintaining national security and accelerate the upgrading of nuclear weapons. Countries that already possess nuclear weapons are seeking to establish a comprehensive nuclear deterrent system. "Nuclear threshold" countries actively seek to become nuclear weapon possessors [2].

2. Methods and principles used in this article

2.1. The Principle of BP Neural Network

BP neural network: the neural network using the Back-propagation algorithm. In the process of simulation and prediction, the network collects the errors generated by the system, and return these errors to the output value, and then use these errors to adjust the weight of neurons to generate an artificial neural network system [3].The network structure is shown in Figure 1.

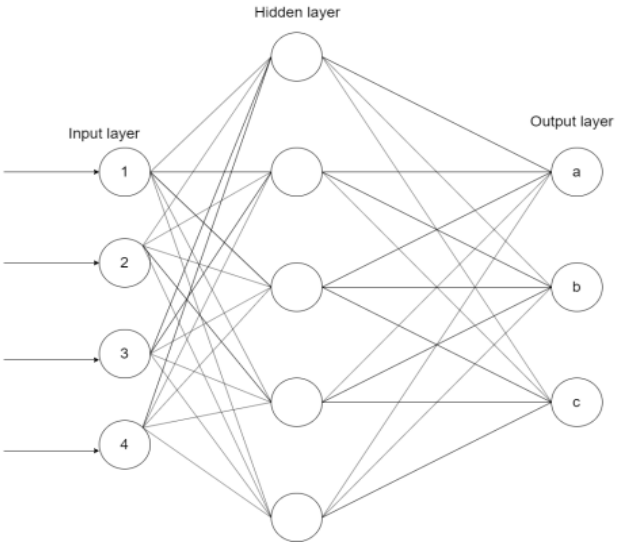


Figure 1. Neural network structure.

2.2. Relevant Principles of Analytic Hierarchy Process

According to the prediction of the time spent by other countries in developing nuclear weapons, Iran and Iraq, the two countries most likely to develop nuclear weapons, will spend about 1Analytic Hierarchy Process (AHP) is a decision analysis method that combines qualitative and quantitative analysis. Less quantitative information can be used to make the decision-making thinking process mathematical. AHP divides the model construction into target layer, criterion layer and scheme layer. Through the construction of judgment matrix, the combined weight vector of different schemes for the target is obtained, and the final ranking result is obtained.

Consistency check: in the actual operation process, we may encounter$a_{ij^*}a_{j^k} \neq a_{ik}$. In this case, the matrix is called the inconsistent matrix, and we need to check whether the inconsistency meets the requirements.

We define$CI = \frac{\lambda - n}{n-1}$, where λ is the largest characteristic root of the matrix, and n is the order of the matrix. When CI=0, there is complete consistency. The greater theCI, the more serious the inconsistency.

To measure the size ofCI, the random consistency index RI is introduced.With different orders, RI values are as follows:

n	1	2	3	4	5	6	7	8
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41

Definition of consistency ratio: $CR = \frac{CI}{RI}$Generally speaking, when CR <0.1, it is considered that the inconsistency of the matrix is within the allowable range and has satisfactory consistency [4].

2.3. Principle of TOPSIS

TOPSIS can evaluate and sort individuals according to existing data. TOPSIS is a method of ranking according to the closeness of a limited number of evaluation objects to the ideal target. The positive ideal solution in the TOPSIS method assumes that each attribute value of a solution reaches the best value of each alternative, and the negative ideal solution assumes that the value of a solution is the worst value of each alternative.

Positive distance formula:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \left(z_j^+ - z_{ij}\right)^2} \tag{1}$$

Negative distance formula:

$$D_i^- = \sqrt{\sum_{j=1}^{m} \left(z_j^- - z_{ij}\right)^2} \tag{2}$$

Evaluation index value:

$$s_i = \frac{D_i^-}{D_i^- + D_i^+} \tag{3}$$

3. Results

3.1. Projections for future nuclear weapon holders

Based on the data, we have obtained the nuclear weapon holdings of various countries in the world over the past few years. Based on the changes in the number, it is assumed that the number of nuclear weapons per six years is related to the previous five years. We use a BP neural network to analyze the data, set the number of iterations to 1000, and obtain a more accurate fitting curve, limiting the error range to less than 1e-5, so that we can predict future changes in the number of nuclear weapons. On this basis, we can calculate the number of nuclear weapons in each country in the next 100 years, and obtain the change in the total number of nuclear weapons in the world in the next 100 years. We also tried grey prediction, fitting regression, and other methods, but the results were not satisfactory, so we chose the results of the BP neural network. The prediction results are shown in Figure 2. Ultimately, the total number of nuclear weapons may remain around 10000 [5].

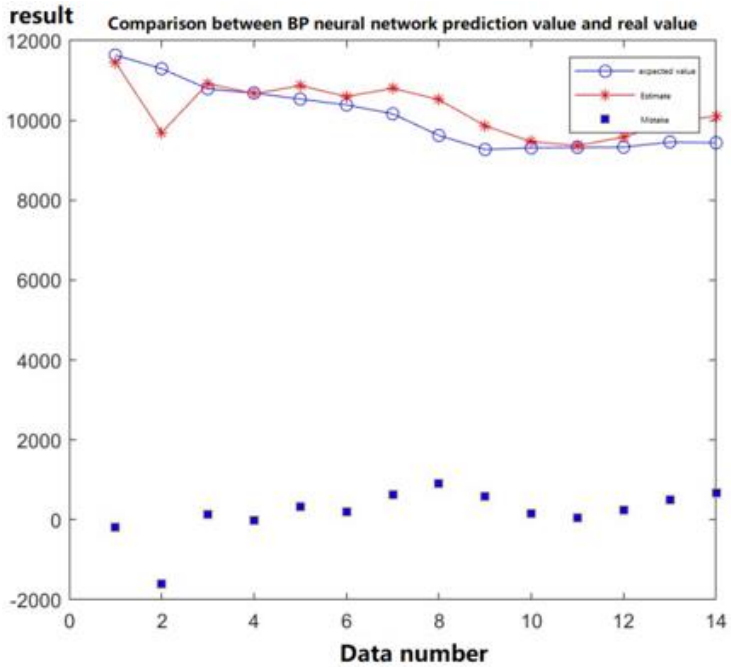


Figure 2. Comparison between BP neural network prediction value and real value.

When the number of hidden layer nodes is 8, the error difference result is shown in Table 1:

Table 1. Error of neural network algorithm.

Average absolute error MAE	MSE	RMSE of root mean square error
443.4981	365169.3537	604.2924

The fitting results of other methods are shown in Figure 3, with large deviations:

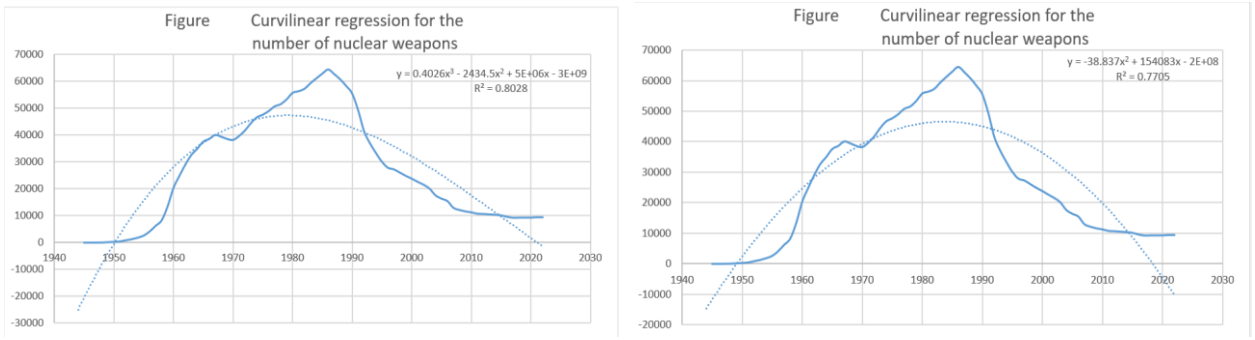


Figure 3. Relevant results of curve regression.

We visually plot the results of neural network prediction using a drawing tool, as shown in Figure 4:

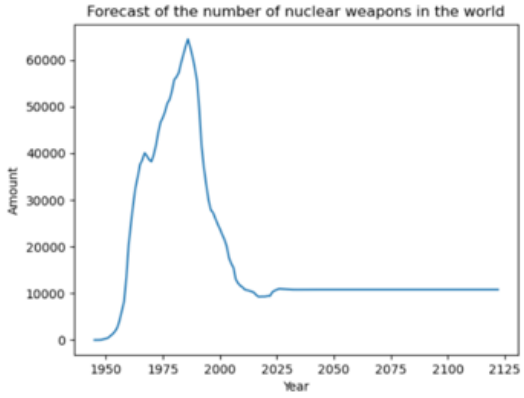


Figure 4. BP neural network prediction results.

Next, we use the BP neural network to predict the number of countries with nuclear weapons in 100 years. The prediction results are shown in Figure 5 below. About nine to ten countries will eventually possess nuclear weapons.

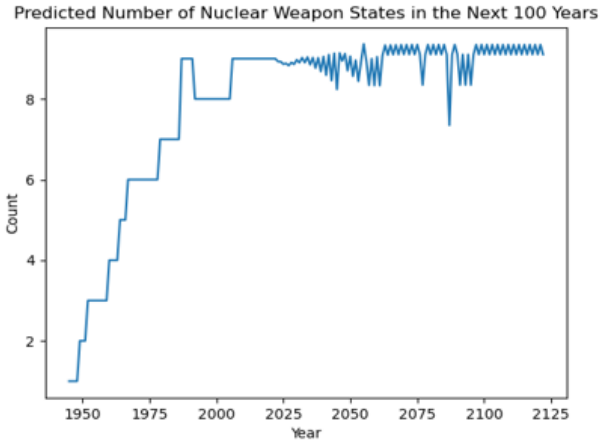


Figure 5. Predicted Number of Nuclear Weapon States in the Next 100 Years.

We can draw from the prediction results that in 2123, there will be about 10 countries in the world that have nuclear weapons, while at present there are 9 countries in the world that have nuclear weapons. According to our prediction a new country with nuclear weapons may be added in 2123.

For this new nuclear weapon state, it is difficult to find out which one it is by using a common algorithm. Therefore, we can use AHP to establish an evaluation system to score countries interested in developing nuclear weapons. We first selected 8 countries with research willingness, but finally left six countries for hierarchical analysis according to research willingness. Our model starts with GDP, advanced talents, research willingness and mineral resources, giving different weights to these aspects, and scores six countries willing to research nuclear weapons. In the process of AHP, we

constructed a 4 * 4 Criterion level matrix and four 6 * 6 Scheme layer matrices [6]. The establishment method is shown in Figure 6.

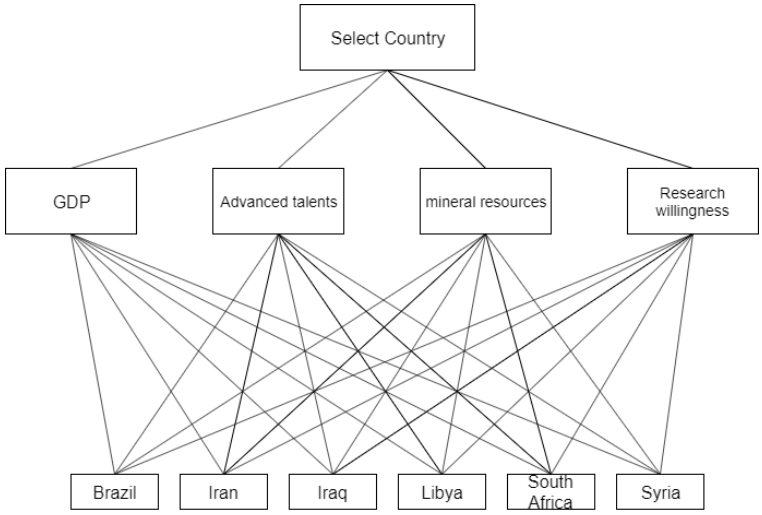


Figure 6. Design flow chart of AHP.

Finally, according to the SPSS system analysis, Iran has the highest score among the six countries, followed by Iraq. According to our previous prediction, if there are 10 countries with nuclear weapons in the future, Iran is most likely to be. The result has passed the consistency test, as shown in Figure 7.

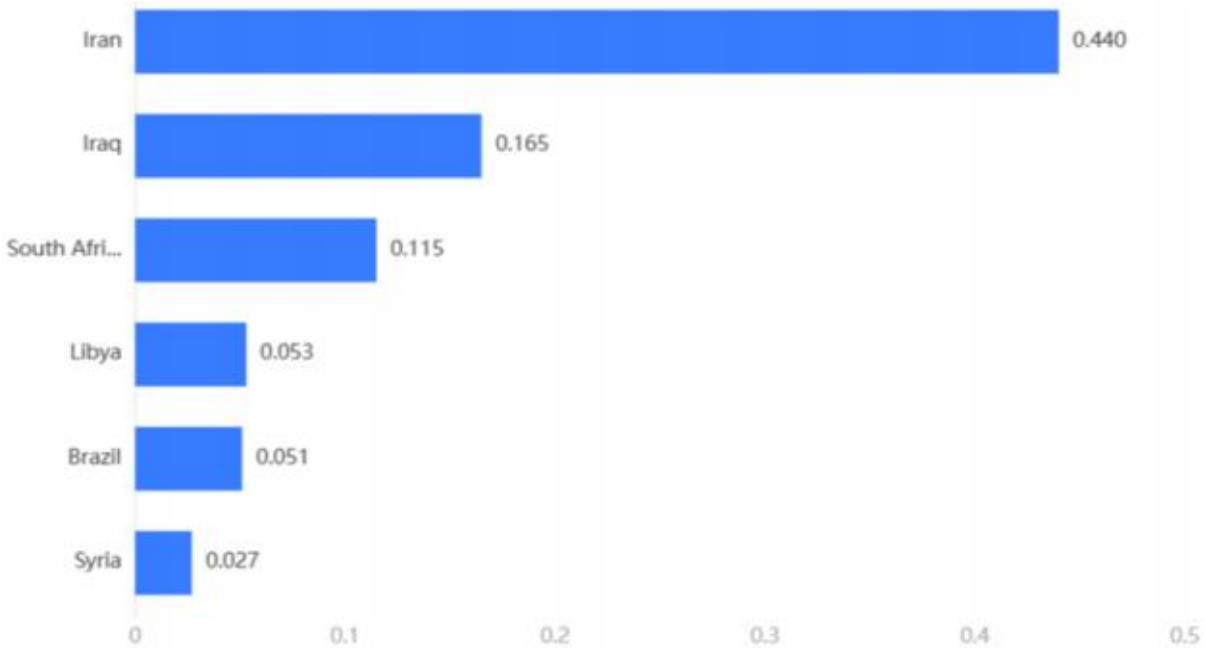
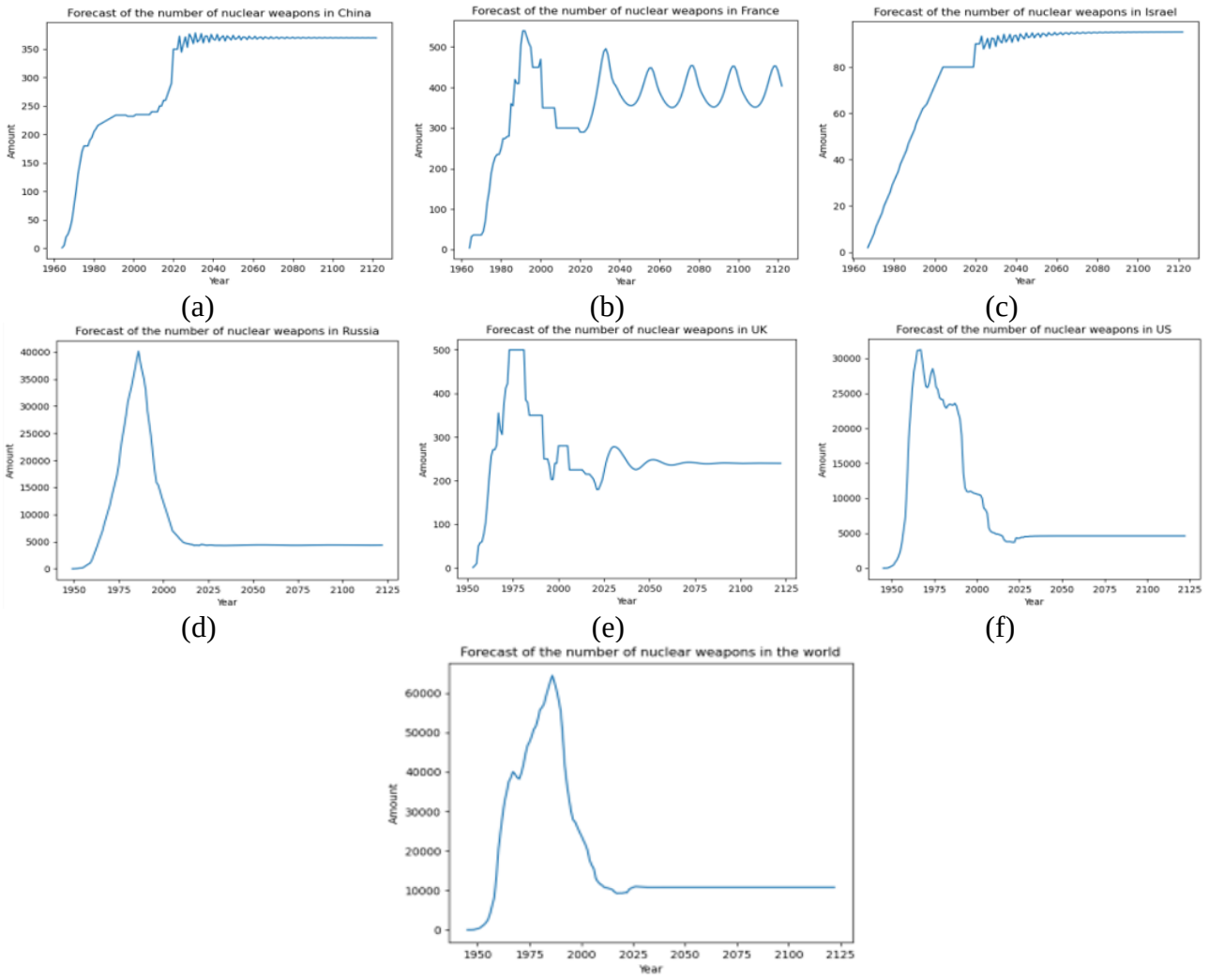


Figure 7. Countries most likely to possess nuclear weapons in the next 100 years.

Similarly, using the BP neural network algorithm, we trained the relevant data of countries that already possess nuclear weapons, and repeated it 1000 times. However, due to the lack of data from Pakistan, North Korea, Israel, and India, neural networks cannot be used for prediction training. We can only approximate linear regression to fit their development curves. Pearson correlation coefficient is high, and the fitting effect is good [7]. The final result is shown in Figure 8.Detailed data is shown in Table 2.



(a) (b) (c) (d) (e) (f) (g)

Figure 8. Predictions from some countries that already possess nuclear weapons.

Table 2. Forecast results for 2123 years for countries that already possess nuclear weapons.

Country	Number of nuclear weapons in 2123
China	369
France	404
Israel	Less than 100
Russia	4357
Britain	239
The US	4602
India	876
North Korea	225
Pakistan	971
Global	13200

3.2. Analysis of global nuclear weapon security holdings

Due to the different destructive power and magnitude of nuclear bombs manufactured by each country in the world, we refer to data and regard nuclear bombs with an explosive equivalent of 100000 tons as standard nuclear bombs. We have found the formula for the range of nuclear bomb lethality:

$$R = C * m^{\frac{1}{3}} \quad (4)$$

C is the proportional constant, which is generally 1.493885. *m* represents explosive equivalent and *R* represents effective killing radius.

To destroy the earth with nuclear weapons is to cover the land area of the earth with nuclear bombs. After querying the relevant mathematical data, we selected the following three coverage methods, and the schematic diagrams of the three methods are shown in Figure 9:

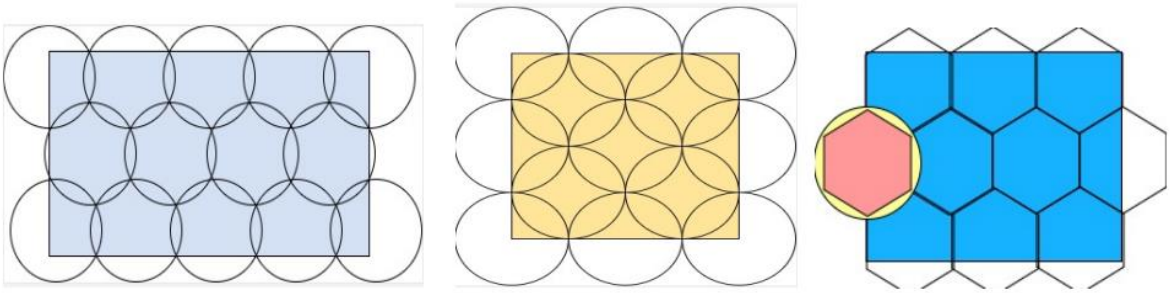


Figure 9. Schematic diagram of three simulated bombing methods.

We define the explosion efficiency as the effective coverage area of nuclear weapons divided by the total explosion area to calculate the efficiency of three types of explosion:

$$\gamma_1 = \frac{16\sqrt{3} * R^2}{14 * \pi * R^2} * 100\% = 63.01\% \tag{5}$$

$$\gamma_2 = \frac{4R * 4R}{13 * \pi * R^2} * 100\% = 39.18\% \tag{6}$$

$$\gamma_3 = \frac{3\sqrt{3}R * 4R}{10 * \pi * R^2} * 100\% = 66.16\% \tag{7}$$

According to the effective area, the third bombing method is the best option for using the least nuclear bombs per unit area. The total land area of the Earth is 149 million square kilometers. After reviewing the data, we know that the average explosive yield of nuclear weapons in the world is 3750.25 million tons. Similarly, based on the third explosion model, we have calculated again that the effective killing radius of this nuclear bomb is 10.77 kilometers, so the area of this rectangular area is 2410.86 square kilometers. Ultimately, it will take 61804 average sized atomic bombs to cover the entire area of the Earth [8].

In the above, we have calculated the minimum number of nuclear bombs required to destroy the Earth. According to data, the total number of existing nuclear bombs in the world is 9440. Assuming that the explosion equivalent of all nuclear bombs is the average value mentioned above, if we uniformly distribute nuclear bombs, that is, there are no other nuclear bombs within the killing range of the nuclear bomb, then 3438216 square kilometers of land can be bombed. Compared with the total land area of the earth, no matter which method is used, the coverage area is far from enough. Therefore, the existing nuclear bombs cannot destroy the earth.

To put it another way of thinking, we can also directly bomb densely populated areas, which is a way of directly killing lives. Taking China as an example, based on data from the China Land Survey and Planning Institute, the total area of urban land in China is about 1% of the total area of the country, calculated based on a total area of 943100 square kilometers. From this, we can roughly estimate that the total area of cities and towns in the world is about 1.49 million square kilometers, and our nuclear bomb count can completely destroy them. According to the World Bank, the global urbanization rate is about 55%. In other words, if we assume that the world's population is 8 billion, then the number of nuclear bombs we currently possess can kill at least 4.4 billion people in the world. But this is still not enough to destroy all humanity [9].

Perhaps we can suppress the continuation of species by destroying the natural environment. The most basic condition for biological survival is food, which comes from cultivated land. The United Nations has issued a red line for the area of human cultivated land, requiring that the area of cultivated land be maintained above the red line to ensure the normal survival of mankind. Therefore, in theory, the maximum number of nuclear bombs that should be limited is the minimum amount required to destroy all cultivated land except for the red line of the cultivated land boundary.

Assume a global population of 8 billion. According to data provided on the official website of the United Nations, the red line area for human survival is 4.24 million square kilometers. Currently, there are 17.3 million square kilometers of arable land in the world, so we need to blow up 13.06 million square kilometers. Considering the self-recovery of cultivated land after a nuclear explosion, we use cellular automata to simulate the fire spread and vegetation survival rate after the explosion [10]. The simulation is shown in Figure 10. About 40% of the population can recover naturally every year.

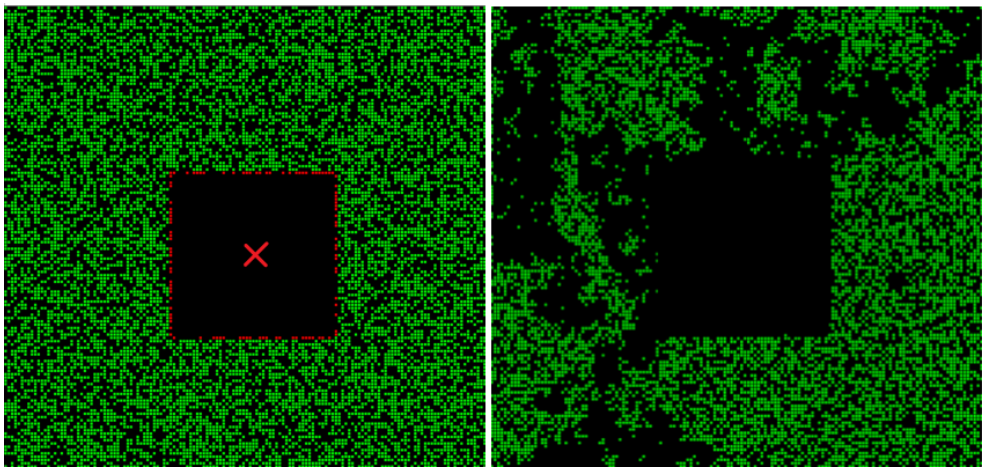


Figure 10. Cellular Automata Simulation of Cultivated Land Restoration.

According to the method shown in Figure 10, we bombed the cultivated land outside the red line equally, and calculated the remaining amount of cultivated land after two, three and four times of bombing. As can be seen from the results, after two bombings, the area of cultivated land recovered in the following years was the smallest. Therefore, we conducted two bombings on each part of the cultivated land to obtain the optimal solution (the Red Cross represents the explosion site, the red dot represents the flame, and the green dot represents the normally growing trees).

After Japan's Hiroshima was attacked by the US nuclear bomb in 1945, plants grew again in some lands of Hiroshima the following year. In this case, assuming that nuclear radiation is barren within one year, we can calculate that 1206 nuclear bombs will be consumed eventually, so it is better not to exceed 1206 nuclear bombs in the world [11].

Since the distribution of the remaining cultivated land is uneven after the bombing in the first year, we cannot use the range covered by nuclear radiation to solve the problem. The method of full coverage is a better solution.

At present, nine countries in the world have nuclear bombs. Considering the great lethality of nuclear bombs, even if a small amount of nuclear bombs are detonated, it will also cause a devastating blow to mankind. The more countries with nuclear weapons, the greater the possibility of using nuclear bombs when war breaks out. According to our analysis above, if we do not restrict other countries from developing nuclear weapons, the number of nuclear weapons in most countries will increase. Therefore, for the safety of people's lives and property, we do not want to increase the number of countries with nuclear bombs in the world. We should maintain the status quo or reduce the number.

4. Conclusions

If we follow the law of the development of nuclear weapons in the world today, the total number of nuclear weapons in the world will reach more than 100000 in 100 years, and the average absolute error of the prediction results is about 443. Compared to 100000, the deviation of this figure is not significant, so it can prove the correctness of the prediction. In 100 years' time, there will be 9 or 10 countries possessing nuclear weapons in the world. Apart from the countries that currently possess nuclear weapons in the world, the most likely new countries in the future are Iran or Iraq.

According to our hypothetical explosion model, although the number of nuclear weapons currently possessed in the world is not sufficient to destroy all humanity, the increase in the number of nuclear weapons in the future would not be a good thing for humanity at the current pace of development. Once nuclear weapons are put into war, their terrifying and destructive power can displace countless people.

In terms of ensuring the minimum cultivated area required for human survival, in order to prevent the impact of nuclear weapons from reducing the cultivated area below the red line of cultivated land, the number of nuclear weapons in the world should preferably not exceed 1206.

Therefore, we hope to use the leading role of the United Nations in international affairs to make an appeal to countries around the world. First, for the sake of human security and world peace, stop researching, developing, and preparing unknown weapons. Second, properly preserve or reasonably destroy existing atomic bombs. Thirdly, we should make full use of atomic fusion, fission, and other reactions, and use them in reasonable places to benefit all mankind.

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