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LIMITS OF SURVIVAL

Forecasting the Future of Japan

[*Seizon no Genkai. Nihon no mirai o yosoku suru*]

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Mainichi Shimbunsha
Tokyo, 1975

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Preface

I would like to explain my original motivation for writing this book. In January 1973, I read the *Club of Rome Report* forecasting the future of the human race. Indeed, I had analyzed the problem in the same way some ten years before.

My analysis lay in the drawer of my desk. As I read the *Club of Rome Report* I was surprised to find a striking similarity to my views in the fundamental concepts and conclusions. Of course, in those days we did not consider pollution as serious a threat as we do today. Even so, my report contained ample data and graphs. Apparently, many scholars today are seriously considering the very problem which had most frightened me. I present this problem here.

I was initially concerned with the special task of analyzing weather forecast records of the last 40 years. I then became interested in forecasting the future. My work brought me into contact with other aspects of the problem apart from weather forecasting. I discuss below the reasons for my interest in the future of Japan.

Forecasting is extremely difficult for it is not just a matter of science. As we investigate further and collect information from economic and political fields, we find that philosophy and religion are also factors in this immense problem. And tackling such a problem alone is like Don Quixote battling a giant windmill.

A clear-cut forecast can be made only with the cooperation of many experts, including scientists, engineers, economists, politicians and philosophers. However, because of their different backgrounds these experts rarely agree. A satisfactory and generally acceptable forecast demands a great deal of time. These experts do better discussing individual problems. For the moment, since individual problems have not been considered in detail, we should study the problem on a macrolevel.

Many dark shadows loom over the future of Japan as indeed they do over the future of the whole world.

If 'progress' continues at the present rate, within a few decades many resources will be exhausted and there will be severe shortages of energy and other resources. As a result, Japanese society may regress to the old Tokugawa Era. Moreover, air pollution and increasing population threaten us with food shortages. A peep into the future brings us anxiety and uncertainty.

An old Japanese proverb says: "The next year is the Devil's joke." Forecasting is always difficult because there are so many qualifications and possibilities. We must also be prepared with countermeasures in theory and in practice. To avoid the threatening problems of the future, we must begin work diligently, today. The right solution to each problem may not be found nor is society amenable to rapid changes. And too rapid change leaves its own victims in its wake.

Decisive, responsible action should be taken to bring about gradual change. With this aim and keeping the future problems of Japan in perspective, we should begin now to prepare countermeasures. My effort here may expose me to severe criticism. However, the opinions expressed in this book are wholly my own and my advice is offered as an individual, not as an official. The future of Japan brought these questions to mind and I wish to make others aware of these matters in their various dimensions.

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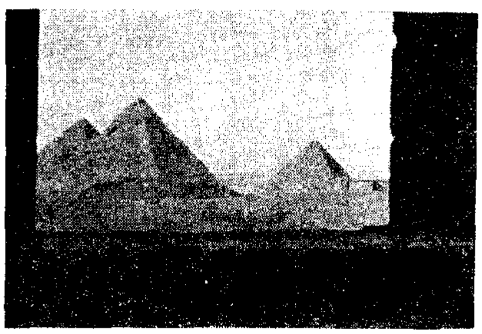
Chapter One

The Crisis of Civilization



Pyramids of Giza, Egypt.

The European people and their great accomplishments will be as vulnerable as the vanished civilizations of the Aztecs, the Incas, the Sumerians or the Hittites.

Arnold Toynbee
Crisis of Civilization

THE BLEAK FUTURE

World War II is 30 years behind us. Even the term 'postwar' is no longer in vogue. Cities and towns today are crowded with people and cars, shop windows are stuffed with articles and neon signs glitter in the night. The skies are filled with jets; colored television and air conditioners are common. In July 1969, man's dream of exploring the moon was realized when Neil Armstrong stepped out on the lunar surface.

While it is true that many people face starvation in the developing countries, in Japan at least the postwar food shortage is long over and now rather morbidly obese children present a new problem. While this reflects good times, if the present trends continue, it will certainly become a nightmare.

Forecasting the future has been seriously attempted in Japan for the last ten years and a society dedicated to the study of future has been organized. In 1959, a Russian, Varishev Gushichev, wrote a book entitled *A Report on the 21st Century* in which he anticipated a bright future. Such optimism was very widespread. Then, in 1970, a book entitled *Scientific Report for the Future*, also by Varishev Gushichev, was published. Is it really possible to dream of such a bright and glittering future? Today many voices advise against such optimism.

The present era is called the 'Showa Genroku Era' and resembles the frivolous 'Genroku Era' (1680-1709); it is not expected to last for long.

Man today enjoys the greatest material benefits in the history of civilization, but prices are ever-rising and people are unanimous in their complaint about straightened circumstances. With ever-increasing population and rising land prices, a common wage earner can no longer be sure of realizing his life's dream of building a small house.

Strolling along one of the streets of Tokyo we experience polluted air, lackluster crowds on the roadside and the roar of traffic. The old quotation, "The great cities are nothing but the graveyards of the human race," is sadly apt today. What would happen if an earthquake like the great Kanto earthquake of 1923 occurred in Japan now? All means of communication would cease functioning, gas and water supply pipes would be destroyed and there would be huge fires everywhere, a monstrous repetition of the deadly death dance of the Kanto earthquake. At the end of the Genroku Era in 1709, living conditions fell drastically. Such a catastrophe could happen again.

Although warfare and natural disasters have plagued man since his earliest days, development has proceeded always surpassing earlier records. In the first half of the twentieth century, we witnessed two wars, fought on a global scale. They were qualitatively different from all earlier wars. The dropping of atomic bombs on Hiroshima and Nagasaki brought World War II to an abrupt end. This 'impressive' achievement of atomic power forwarned of the possible downfall of mankind.

The postwar confrontation between the two superpowers, the United States of America and the Union of Soviet Socialist Republics, originated with the explosion of the experimental hydrogen bomb on the Bikini Islands. This resulted in the tragic incident of the Japanese ship *Fukuryu Maru*. We are reminded here of the famous story from the Arabian Nights of a fisherman and a genie. We are like the fisherman. After casting our net, we lift it and, finding it heavy, remove the lid of the pot only to encounter the monstrous genie of atomic power. The human race has arrived at a point at which our very existence is threatened. The fisherman exercised sound wisdom, shutting the genie in and securing his own happiness. Now we wish we had had the intelligence of the fisherman from the Arabian Nights!

This is not the only dark cloud hanging over the future. World population continues to increase with tremendous speed and half of it still faces starvation. Surely this should arouse us to action.

Furthermore, if economic growth continues at the present rate, fossil energy--the foundation of today's civilization--will be exhausted in a few centuries. Petrol-based energy will be depleted in a few decades according to one recent forecast and there seems to be little hope for the prolonged life of iron ore or other metal resources. In Japan, the situation is still worse. Many of our mineral resources are nearly exhausted now.

CIVILIZATION AT THE CROSSROADS

The progress of civilization has lengthened the span of human life but neuroses and crimes of various types have increased. Society is also faced with the need to care for an increasing population of the aged.

In recent years, environmental pollution, due to the proliferation of automobiles and enormous industrial establishments, has become a major global problem. In Japan, pollution has led to diseases such as Minamata disease, caused by mercury contamination, and Itai Itai disease, caused by cadmium contamination. Pollution has increased to such an extent in Japan that it is now known as one of the most advanced and yet one of the most polluted countries in the world. Contamination by insecticides has been detected even at the South Pole where no humans live. The International Conference on Human Environment, held in June 1972 in Stockholm, focused attention on how important the environmental issue has become.

While modern life proceeds to pollute the environment climatic conditions of the world are deteriorating. Temperatures have fallen in high latitude areas and this is a red danger signal for a world food crisis.

Toynbee warned: "Civilization has reached its period of trial." Can mankind overcome all these difficulties? Is it desirable to allow these problems to take their own course, as a fatalist might recommend? Unattended, these problems would soon lead to a real population explosion. This could lead to an atomic war from which no one could guarantee that the world would ever return to its original state. Further "advance" of civilization may lead mankind to the era of giant reptiles which appeared in early geologic history.

In recent years, awareness of these problems has spread rapidly throughout the world influencing public opinion. For instance, about ten years ago, the conference held at Bagwash and attended by nuclear scientists from the East and West had as its basis Einstein's theories. As a result a movement began for the total eradication of all war. In 1970, Aurelio Vecini of Italy undertook the promotion of this cause and founded 'The Club of Rome.' This club is a private international organization. No government officials are included among the members, perhaps to prevent political interference. Its aim is to find ways to prevent the potential hazards arising from progress in military technology, the population explosion, increasing environmental pollution and diminishing natural resources--all objects of serious concern in recent years.

As a result of these activities, the Massachusetts Institute of Technology (M.I.T.) in the United States was requested to undertake studies of these dangers to mankind. The paper ultimately published, "The Club of Rome: A Report on the Crisis of Mankind and Its Limits of Growth," inspired similar thinking in various corners of the world and its echoes are still being heard.

Figure 1 will help to explain our point. This chart shows a forecast of the future of the world. Changes caused by changes in physical, economic or social relations have not

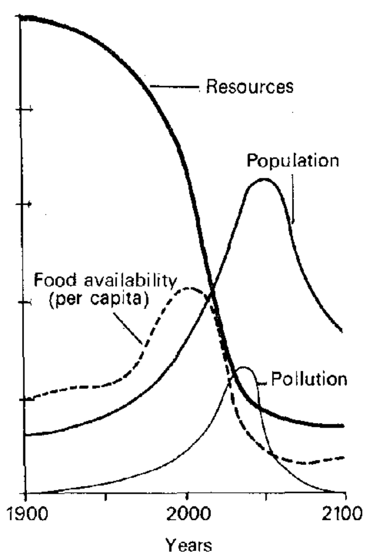


Fig. 1. Future anticipation of resources, population and food contamination in the world according to the model.

been considered. The chart shows the patterns of population, resources, pollution and so on calculated for the future.

As these curves indicate, resources will run dry by the year 2000 and by the year 2030 there will be conditions of serious scarcity. The world's population will continue to grow, reaching a peak in the year 2040 and then declining rapidly. At present, the per capita food consumption is increasing, but by 2010 it will drop abruptly and conditions of starvation will appear by about 2040. Environmental pollution will increase more rapidly and with the decline of industries in 2030 it will decline again. A crisis of civilization will thus loom after 30 years, a bleak forecast for the twenty-first century.

As these results are based on certain assumptions, the course of events is certain unless the environment changes. In this case a change in the environment means a change in people's attitudes and conduct once they are fully aware of the impending crisis. If we forecast the future assuming changes in the environment, we will find that this will affect the future course of events. Unless this pattern changes qualitatively this crisis of civilization must be accepted without reserve.

The common man today may wish to ignore this problem as it seems so remote. From one point of view this is not unreasonable. The solutions of the problem are beyond the scope of the common man; it is a task for society as a whole. Countermeasures are very complicated as they require inputs not only of scientific technology, but of economics and politics and new concepts and philosophies.

Despite the remoteness of the crisis and your indifference, you cannot dodge it. The crisis of civilization is not a fantasy of a remote future. The catastrophe will strike within 20 to 30 years while many of us are still alive to face it. However, it will be many years before the masses understand these problems and undertake appropriate countermeasures. The crisis of civilization is not yet so serious as to call for panic but we must act. We must investigate the effects of human activities on the natural environment. We must study the increasing environmental pollution. Recognizing that current habits and policies adversely affect human existence, we must take steps to control industry and check the growth of pollution. We must then determine the optimum number of people which can be accommodated on this earth. If we expect further growth in world population, we must find a way to curb it. To bring these measures into practice, detailed investigation, planning and research are necessary. And, we must hasten to implement countermeasures as they are found effective.

Chapter Two

Population Explosion

Some of the participants at the World Meteorology Conference held in Geneva, 1971. (Delegates from over 100 countries attended the conference).

The sky was full of ripples of heat,
There came a sound as of a wind,
Rushing over the countless slender
  branches of trees of a forest.
Over the horizon, there loomed a
  rosy soft cloud.
Looking like the carrier of a hail storm.
It rose!
But
Oh my God!
It was a vast swarm of rapacious locusts!

A. Daudet
Lettres de mon moulin

HISTORY OF POPULATION GROWTH IN JAPAN AND THE WORLD OVER

Society has today reached a turning point. In recent years problems never conceived of earlier have appeared in the news media. Increasing pollution, vanishing energy resources and food shortages due to abnormal climatic conditions are becoming daily facts of life. The astronomical rise in land prices is becoming a political issue.

One of the primary reasons for these complex problems is the rapid increase in population. Population increase in this century in Japan as well as throughout the world has been very rapid. Indeed, it has been called a population explosion. Moreover, the striking advances in scientific technology and the growth of the economy have affected every aspect of human activity and the environment as a whole.

Let us examine how the population of Japan and that of the world increased in earlier times. Research on Japan's population (the study by Sekiyama Naotaro) provides estimates for ancient times.

The results of a census conducted by the government after the fifth year of Meiji (1872) are available and are quite reliable. In the Tokugawa period, also, the Shogunate carried out many fairly scientific surveys, yielding reasonably accurate figures. Before this point the reliability of data is dubious as population was calculated on such bases as the area of cultivated rice fields.

According to these reports, the population of Japan during the Nara period was 6-7 million; from the tenth to the fourteenth centuries it rose to 10-11 million and in the sixteenth century it reached 18 million. Thereafter there was great increase in population, but when an isolationist policy was adopted in the Tokugawa period, it remained stable at about 31 million for over 200 years.

After the Meiji Restoration (1867), Japanese culture experienced a renaissance and industrial development; population then increased rapidly until it reached the present level (see Table 1 and Fig. 2).

In the case of world population, census methods have differed from country to country and there are places for which no reliable census figures are available. It is thus difficult to arrive at an accurate figure. Recently, however, accurate figures have become available from UN statistical reports.

The world population in prehistoric times is not known, but it is estimated that about 10,000 B.C. the population was some one million. As the human race progressed from the

Table 1. Changes in the population of the world and of Japan (Figures in millions)

Year	World	Japan	Percent increase in Japan
1800 A.D.	910	30.5	100
10	950	31.0	102
20	990	31.2	101
30	1035	32.0	103
40	1080	32.0	100
50	1130	32.0	100
60	1210	32.5	102
70	1300	34.5	106
80	1395	36.7	106
90	1490	39.9	109
1900	1590	43.9	110
10	1620	49.2	112
20	1715	56.0	114
30	2070	64.5	115
40	2295	71.9	113
50	2517	83.2	115
60	2990	93.4	112
70	3632	103.7	111

Neolithic to the Bronze Ages, the population is believed to have increased rapidly.

The reliability of population estimates increases with the advance of history. World population is assumed to have been 280 million at the time of Christ. Population remained stable then until around 1000 A.D. The minima occurred around 700 A.D. This was the dark age of the medieval period when religion held sway over society and it is almost certain that population decreased.

During the Tokugawa period in Japan there was little appreciable change in population; the same was true for world population as a whole. This is an important historical point as we consider population changes thereafter.

After the year 1000 A.D., population began to increase once again. The black plague epidemic of 1350 caused a temporary reduction but after the Renaissance, the growth rate increased and population accelerated to the present level (see Fig. 2).

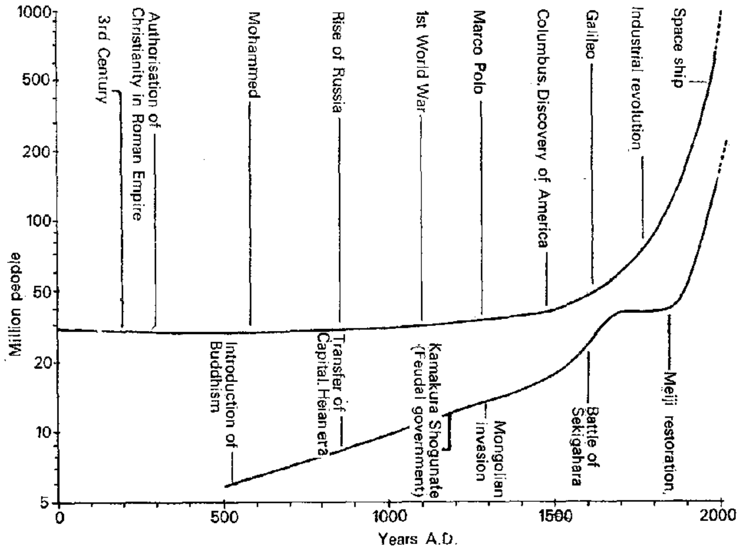


Fig. 2. Changes in the population of Japan and of the world.

This information indicates that the populations of Japan and of the world increased, stabilized, increased again and stabilized at that level. This cycle repeats itself. Each period of rapid increase coincided with the development of new technology which increased production.

FUNDAMENTAL PRINCIPLES OF POPULATION GROWTH

Let us express the principles of population growth in simple terms. Population provides the basis for the political and economic policies of a country and for this reason censuses have been conducted since ancient times. In Japan there is a record of a population survey conducted in the twelfth year of Emperor Sujin (84 B.C.), but censuses assumed scientific proportions only in the seventeenth century.

In 1676, Petty of England published a book entitled *Political Computations*. This was a predecessor of modern statistics and population theory (demography). Today one of the main topics in statistics is population. At first this subject was simply concerned with the number of people. Later many scientists published papers on population theory; these included a theologian of Prussia, J.P. Sussmilch, the discoverer of Hailey's Comet, and J. Bernoulli of Basel University.

The most important paper among these was 'The Principles of Population' by Malthus which was published in 1798. He presented three doctrines or theories:

1. Living things strive for survival and hence if the surroundings are favorable, their population increases rapidly.
2. If the number of living things becomes surplus, then space and food are in short supply; this limits their number to a stable value.
3. When the population exceeds its optimum limit, which is determined by a certain standard of natural resources, poverty spreads and calamities follow.

These theories are among the points made in Marx's *Das Capital* and many papers have been published opposing them. For example, it has been argued that because the poor tend to have many children, the population may not necessarily decrease in the event of a food crisis and that as the population increases, food production will also increase; therefore, the quantum of food does not determine the volume of population and so on. These counter-arguments have some validity and while we cannot wholly espouse the Malthusian theory, we recognize that it was a major step in defining principles of population growth.

Such discussions are theoretical. To consider the actual patterns of change in the population, we must convert the data into a mathematical equation. In 1845 a Belgian mathematician formulated population increase as follows:

$$\frac{dN}{dt} = \frac{bN\,(K-N)}{K},$$

where N is population, t is period and K and b are constants.

The solution of this equation is:

$$N(t) = \frac{K}{1 + Ae^{-bt}}$$

This means that population increases exponentially and when it reaches a certain level the rate of increase decreases and ultimately equals the constant K.

The constant b in this differential equation is the rate of increase in population when the natural resources for survival are abundant. K represents the population value controlled by limited resources, that is, the optimum value. In other words, b is the natural rate of increase and K is the saturation point of the population.

He called the 'increase curve' of this equation the 'logistic curve.' This equation is valid not only for population, but for increase in the height of human beings, the development of industry, increase in the speed of means of transport and so on and hence it is called a 'growth curve.'

This, of course, is just one mode. Actual population growth does not necessarily follow this curve. The natural growth rate affects the saturated population in various ways and is not necessarily constant in terms of space or time. In general, if industry flourishes, even a saturated population may increase further. As medical science progresses, the life span increases and the natural growth rate increases. The mortality rate changes according to the age group. It is usually higher for old people and it increases as pollution becomes denser. Opinions vary about the effect of natural resources on the saturation point of a population. For example, if there is trade with the outside world then natural resources become the economic controllant of the productivity of the earth. This is because goods produced in industry can be exchanged for food thus making survival possible. But for the earth as a whole, if there is no such exchange with other planets, food can be thought of as a limited resource. Of course, this may change with different standards of living, but its latitude is very small. This theory is frequently used to determine the size of ancient populations.

This equation, however, simplifies the problem, for in modern research it is also necessary to consider certain aspects of ecology for which this mathematical expression is inadequate. If we consider it a one-sided prediction and try to divide the problem into many small phases, undetermined parameters multiply increasing the chance of error and the prediction may become erroneous. In some cases if the meaning of constants and coefficients is not properly understood, we cannot interpret the population in its proper perspective. From this point of view, if we treat the equation as a kind of model, it is not totally unrealistic.

The results of experiments conducted on insects and bacteria in laboratories conform to the above equation. There may be some reluctance to apply these results to human beings, but in terms of food consumption they are valid. From past experience, within a limited period, this phenomenon can also be qualitatively observed.

ESTIMATES OF POPULATION GROWTH IN THE FUTURE

Based on the above, let us try to predict the population of the world and of Japan in the future. First, if we assume that the saturation point of the population is very large, then according to this equation it follows that population increases exponentially. The rate of population growth in Japan in recent years has been 1.1%. If the population continues to grow at this rate, by the year 2000 it will be 142 million and by the year 2050 it will be 240 million. On the other hand, the world population in 1970 was 3600 million and in the 1970s it is increasing at a rate of approximately 1.8%. If it continues to grow like this, by the year 2000 it will be 6200 million and in 2050 it will be 15,000 million.

Such a rapid increase may not actually occur, however, because it would mean a rapid deterioration in standards of living and steps may be taken to control this increase.

Returning to the logistic curve, let us estimate the value of a saturated population. In fact, there are many undefined factors and it is very difficult to estimate such a value. But during the period of isolation in the Tokugawa period, the deciding factor was rice production. During that time whenever poor harvests occurred, a decrease in the population could be clearly seen as a result of food shortages.

Today, however, Japan is not isolated. There is an exchange of goods with other countries. In terms of food, rice is no longer the sole basis of the diet and its production alone does not determine prosperity. So, while we do not expect food production in Japan to increase further, the country is not isolated from others. Industry can flourish, export can be increased and food can be imported in return, thereby allowing the population to grow.

This point of view is worth considering, but it has its limitations. World population is increasing rapidly and if it so continues, the quantum of food produced by the entire world will reach a plateau in the very near future. Indications of this are apparent even now. We are looking for more seafood for this reason. The sea covers 70% of the earth's surface and in early times marine resources were considered unlimited. Production was limited due to primitive fishing techniques and the position of supply and demand. Now, because of bigger catches, marine resources are diminishing. This problem has become an issue in the discussions on fisheries between the USSR and Japan and between the USA and Japan. Similar problems will arise in the case of agricultural production too.

Even though there are alternatives to rice, rice is important as a food index. It is the staple food of Asia, including Japan, and is likely to remain so in the future. Let us then consider rice as a factor determining the saturation point of population.

We look first at variations in rice production as they occurred in the past. Figure 3 shows the changes in total rice cultivation in Japan and the yield per 'Tan'* according to the financial year. As agricultural production is greatly affected by weather conditions, these changes are large, but in general production has been increasing since the Meiji period. The yield per 'Tan' has also been increasing and, compared with that of the Meiji period, it has increased 2.7 times. This increase was not gradual but corresponded to advances in agricultural technology.

There was a jump in production around 1910 and 1950. The rise was particularly steep around 1950 and since 1970, due to preventive measures, it has been approaching the saturation point. The area of rice cultivation in Japan did change, but not significantly, so the total rice production and yield per 'Tan' are proportionate. This is clearly shown in Fig. 3. Considering these facts, if we extrapolate the curve further, rice production in the year 2000 will be about 14.5 million tons. From this standpoint we may consider the increase in rice production since the Meiji era as a supporting factor in

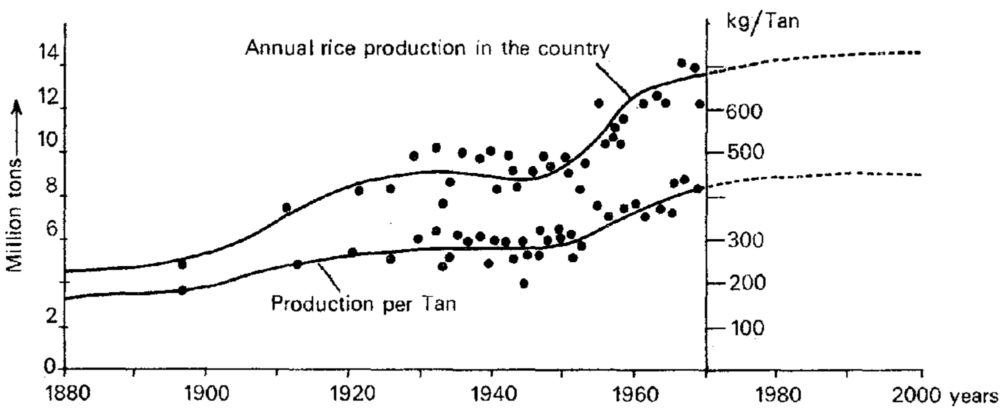


Fig. 3. Rice production and yield per unit area (measured in 'Tan'), 1880-1970.

*Japanese land measure = 991.7 m^2 or about 0.245 acre--General Editor.

the rapid increase in Japan's population. If we use this factor in the forecast of future population increases, rice production around the year 2000 will be 4% more than in 1970. Hence with the same 4% rise, population may reach 108 million.

According to the Bureau of Statistics of the Prime Minister's office, the population is going to be 116 million in 1980, 125 million in 1990 and 132 million in the year 2000. We do not know which figure will prove correct. If we assume that one of the predictions of the Bureau of Statistics is correct (132 million in 2000), then only 82% of the rice necessary for sustaining this population will be available in Japan and the remaining 18% will have to be imported. This premise is based only on rice, but we must also consider other food, a substantial portion of which is imported even now. While present needs can be met, we must recognize that food is becoming scarce the world over and by 2000 A.D. it may be impossible or very difficult to import sufficient food. Under such circumstances, unless population is controlled, the food available per person will decrease and living standards will fall. These consequences are inevitable.

Another factor in population growth is the effect of pollution. While pollution is increasing on a world scale, the life span of human beings, lengthened as a result of medical progress, may be curtailed at this point and may even decrease. In population theories developed so far this aspect has not been considered, but under current realities it must be examined.

The effects of increased pollution will reduce the rate of population growth and even worse, reduce the population. Research on this subject is inadequate and no figures are available on which to predict the impact of pollution on population levels. However, we expect that impact to be severe and to curtail population growth. In that case the population of Japan in the year 2000 may be less than that predicted by the Bureau of Statistics.

TWENTY BILLION--THE SATURATION POINT OF WORLD POPULATION

We now consider world population. The world is an isolated unified society unable to import foodstuffs from other planets. If food is not sufficient there will be immediate starvation. Even now food is not distributed according to population distribution so some regions have a sufficient supply of food and others an insufficient supply.

The availability of food itself must be considered. From this point of view, the saturation limit differs greatly for the population. The available calorific value, according to one survey, could support about 36 billion. If a better standard of living is desired, it could support about 25 billion. It is difficult to determine the correct values, but a population of 30 to 40 billion can be supported on this earth.

At present the world population is about 3.6 billion and at the present rate of growth with the population doubling every 40 years, it will reach that level in 130 years, in the year 2100.

Let us consider the saturation point of population from another angle. Population density in Japan is 272 per km^2. If the population density of the entire world reaches this level, world population would be 39 billion or 11 times the present figure. If the population density of the entire world were equal to that of the United States, 22 per km^2, the population of the earth would only be 3.3 billion, approximately 90% of the present population.

In Japan food production is clearly insufficient for the population and in terms of calories about 40% is imported. In the USA food production is abundant and a large amount of it is exported. The food supply in Japan is supported by imports. From this point of view, it is not preposterous to assume that the saturation point of world population is 20 billion. But if the desired standard of living in every country is to be equal to that of the USA, then not only is further population growth impossible, but population level may have to be reduced.

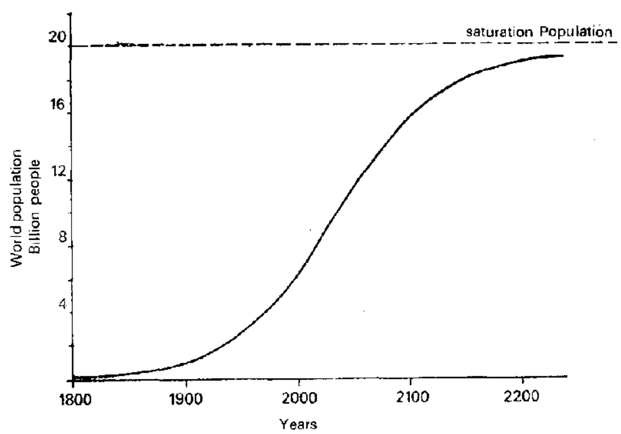


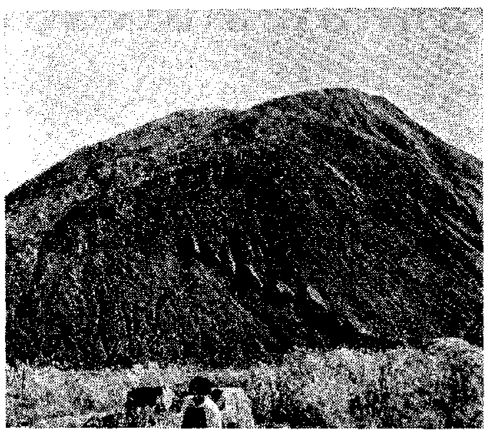
Fig. 4. Expected growth of population.

This problem, therefore, is not only a scientific one but a social and economic one too. The individual human being's attitude toward life, his willingness to limit population and his desired standard of living are all aspects of the saturation point of world population.

Assuming that the present saturation point of the population is 20 billion and the growth rate of the population is 2%, if we calculate the world population by extrapolating the logistic curve, it appears to be less than this as shown in Fig. 4. That is, by 1980 it will be 4.2 billion, by 1990 it will be 5.6 billion. By 2020 it will almost double to 7.4 billion. The figure arrived at by the United Nations has some latitude, but they estimate that by 1990 the population may be about 5.2 billion and by 2000 about 6.1 billion which is more than the predictions in Fig. 4.

Chapter Three

Shrinking Resources



Mt. Bota (Kawasaki-machi, Shizuoka Prefecture).

No matter where you may be living, it is certain that manpower and material resources must both be treated with importance. One should not waste these things by only thinking about the things that meet the eye.

The speeches of Mao-tse Tung

INTRODUCTION

Gold is a vital and powerful metal. For thousands of years man has adored it and allowed it to control the economy.

In Japan, the golden hill of Sado Island was discovered in 1601. The Tokugawa family treated it as a heavenly boon and accelerated development work which became the motivating force of the economy during the Tokugawa Shogunate. During the last days of the Tokugawa period production fell and after the Meiji restoration the mine was acquired by the government and transferred to the Mitsubishi Mining Industries. In Showa 27 (1952) gold production fell drastically and today the mine is virtually abandoned.

This is an example of the problem of resource depletion and illustrates how an existing resource faces exhaustion at some point. But what is a resource? All materials necessary for our survival, including energy, are resources.

This simple definition is inadequate for our purposes. A dictionary tells us that, in a general sense, a resource is a useful product of technological development. In a more restricted sense, it is something present in nature.

Again, Mr. Kunimatsu says that is something available in nature which specifically provides a basis for the economic structure and which can be used for economic benefit.

The use of the word 'resource' is not very old. In fact, the American President Theodore Roosevelt used it for the first time in his policy speech of 1909 while discussing the conservation of natural resources.

The word later spread into use in every aspect of life. On May 27, 1927, a 'Resource Bureau' was established in Japan under the auspices of the prime minister's portfolio.

Among the principal reasons for Japan's involvement in World War II was the need for additional resources. After the war, in 1956, when the Bureau of Science and Technology was established, the Resource Bureau was again constituted and is now called the Department of Resource Surveys.

The importance to the government of natural resources is now apparent, but we must always keep the economic dimension in view as a resource is never considered on its own but in terms of its potential value.

For example, almost all the known elements exist in sea water and if we calculate the total amount of these elements in all oceans, the quantity will obviously be large. In 10,000 tons of sea water we can find 0.3 g gold and 2 g silver. The total quantity of sea water on earth is 1.46×10^{18} tons which means that the total quantity of gold and silver available is as much as 15 million tons and 290 million tons, respectively. But sea water cannot be treated as a source of gold and silver because, even though it is present in very large quantities, extensive efforts would be required to extract it in any useful form and it may not then be economically viable.

RESOURCES CHANGE WITH TECHNOLOGICAL DEVELOPMENT

We thus find that resources follow the second law of thermodynamics. According to this law, "whenever any temperature difference exists, heat flows from a body with a higher temperature to the one with a lower temperature and does not flow otherwise, thereby creating a temperature balance." Here entropy is used as a measure to indicate heat distribution. These factors are not easily explained but we add that heat conserves while distributing. Therefore, when the temperature difference is great, entropy is small and heat flows from the higher temperature level to the lower temperature level thereby reducing the temperature difference while increasing the entropy at the same time. The second law of thermodynamics is also known as the principle of entropy.

Resources such as the metals we need in everyday life are consolidated at one place and can easily be separated. In terms of thermodynamics this is a state of lower entropy. The metal is used as a resource in various applications and while being utilized spreads over a wider region. It is difficult to reconsolidate the same material and hence it loses its status as a resource. This is a state of higher entropy, in terms of thermodynamics.

Another important point is that a resource is not a fixed thing. It can change with advances in technology. A particular substance is not considered a resource while its usefulness remains unknown. It becomes a resource only when technological development reaches a stage at which it can be utilized.

Until World War II, uranium had no use. It was sometimes used as a paint in ceramics and glass. In research by Madam Curie on radioactive elements, radium was discovered from uranium ore and just before World War II the phenomenon of nuclear fission of uranium was discovered. This made possible the harnessing of atomic energy. Uranium prices rose sharply since it could now be used in atom bombs and as fuel for nuclear reactors. It thus became an important resource overnight.

The use of various resources increases with technological development but the supply of resources is not inexhaustible.

Possibly future explorations will unearth new metals or new deposits. For example, Germany had a world monopoly of californium ore in the past. During World War I its supply was suspended. New sources were then tapped and the Karlsbad deposit was discovered in New Mexico.

Later another large deposit was found in central Canada which had a few billion tons capacity. This mine is expected to supply ore to the entire world for a few centuries.

Sometimes the value of an important resource decreases with the discovery of a substitute. Gun powder (KNO_3) is an example. In 1908, in Germany, Harber replaced gun powder by successfully arresting the nitrogen in the air. Similarly, during World War II, synthetic rubber was developed in the USA to replace natural rubber. The new substance proved to be better than natural rubber.

Resources can be exhausted and yet with advances in science and technology new resources find vital application.

FAST DIMINISHING METAL RESOURCES

The properties of various metals have made these substances vital aids to development and if the human race had not discovered them, civilization might not have taken its present shape.

About 3000 B.C. methods for smelting copper were developed and varieties of bronze were made by adding zinc in various proportions. These discoveries accompanied an important step forward in civilization. Later, these metal objects were largely replaced by iron when it was discovered. But since copper conducts electricity easily and has important rust resistant properties, it is still widely used to meet particular needs. The total amount of available copper ore for copper is estimated at 320 million tons, according to a 1968 estimate. Yearly consumption of copper as of 1970 was about six million tons. If we use copper at this rate it will last for only another 50 years.

Iron is also an old metal. Initially meteoric iron was found but when the method of iron extraction using charcoal was discovered, the uses of iron increased rapidly.

Iron soon surpassed bronze which was used earlier. The Greek civilization which began about 500 B.C. is said to have been built with the help of iron.

After the Renaissance, about 1500 A.D., the blast furnace method was discovered, in 1700 the coke blast furnace method and in 1790 the Badore method. It was then possible to produce iron on a very large scale. Iron production then increased in geometrical progression every year. For example, if we study the yearly production of pig iron as shown in Fig. 5, we find that production was only about 820,000 tons in 1800, but increased seven times to 39 million tons in 1850, 50 times to 5,820,000 tons in 1900 and by 1950 increased about 160 times to 132.1 million tons. At the beginning of the Showa period (around 1925) there was a world-wide recession resulting in a temporary drop in production. But production otherwise increased in geometric progression and by 1970 had reached a level of 430 million tons.

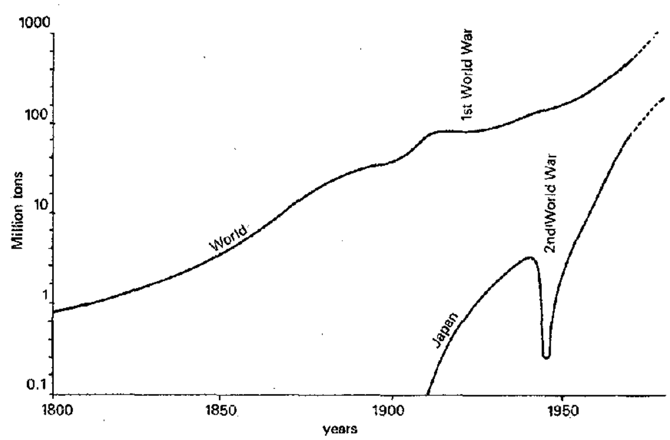


Fig. 5. Shifts in the production of pig iron in Japan and the world.

In Japan, the increase in production was slightly faster than in the rest of the world. There was a sudden drop after World War II, but it then increased greatly.

Iron was used to make agricultural instruments and weapons in early times but today iron finds many further uses in machines, transport, building materials and so on. Therefore, the amount of iron used can be a parameter of the level of civilization. For example, the amount of iron used per person in 1963 in the USA was 540 kg, in Sweden 545 kg, in W. Germany 473 kg, in Australia 389 kg, in the UK 368 kg, in the USSR 344 kg, in Italy 277 kg, in Japan 258 kg, in Spain 100 kg, in Brazil 44 kg, in the UAR, China, India each 16 kg and in Indonesia 2.5 kg. Ours is surely 'The Steel Age.'

But how long can this age continue? So complex a problem cannot be easily summarized. Furthermore, the various surveys of the world's iron resources are based on different methods and assumptions. According to a German survey in 1913 the possible stock of iron in the world was 167.7 billion tons, while the confirmed quantity was 57.8 billion tons. Assuming the percentage of iron alloys to be 49%, the available quantity of iron becomes 29.4 billion tons.

These figures are half a century old. According to a recent survey of natural resources a new estimate of 45 billion tons has been made. Even with the inaccuracies of estimates, the amount does not change appreciably and 45 billion tons can be taken as the present available quantity. The yearly production of iron in 1970 was about 600 million tons; if we continue to use iron at this rate, iron will be exhausted within 75 years.

Aluminum is also an abundant element. It covers about 8% of the earth's crust. But only very recently have we succeeded in extracting it in metal form. In 1827, a German, Wieler, reduced aluminum chloride for the first time with the help of potassium. At the time of Napoleon III, aluminum was considered an equivalent of white metal (nickel) and Napoleon used aluminum utensils on his dining table to display his grandeur.

The discovery of electrolysis in 1886-87 was a step toward industrialization. Aluminum has a low specific gravity, it is comparatively strong, its surface is self-protective from rust and it is a good conductor of electricity. These properties increased its usefulness and in many cases aluminum has replaced iron or steel. Today it is used in airplanes and trains as well as for household items.

Aluminum compounds exist in abundance in the earth's crust, but only bauxite and cryolite ores are economically practical. These deposits are found mainly in the USA, the USSR and France. In Japan the stocks are negligible so we must depend on imports of these ores. Electrical power is generally used for smelting so production varies according to the cost of electricity.

We have discussed here only copper, iron and aluminum. The resources of these metals in Japan are limited in relation to the population, indeed almost nil. So even to maintain the present rate of production, large quantities of ore must be imported. This is a disadvantage to Japan's economy, but one that must be tolerated.

Japan has an extensive coastline and good harbors, both of which encourage sea trade. To smelt the ore, we need coal but these substances are not available in the same place. Hence, one of them must be transported to the place where the other is available. The mining area is not necessarily the most convenient place for metal extraction and this is advantageous for Japan. Other requirements for smelting such as electricity and water are also readily available in Japan as there is ample rainfall.

The heavy demands on copper, iron and aluminum suggest that the supplies of these substances may soon be exhausted. As yet no formula has been found to precisely predict these depletions.

More accurate surveys of resources and further technological advances may reveal larger deposits or more effective uses of resources. Furthermore, changing patterns of consumption may alter the demand for these resources. If we take the recent survey of resources as a point of reference and assume that the consumption pattern will continue as it is now, the duration of presently known supplies can be predicted as in Table 2. While these figures are not exact and may change for various reasons, this table indicates that the life of almost all resources is about 100 years and some resources will be exhausted within 20 years.

Table 2. Mineral resources and their life

Resources	Years
Iron ore	75
Bauxite	160
Nickel	130
Copper	53
Lead	28
Zinc	17
Coal	180
Oil	30

CHANGING ATTITUDES TOWARD RESOURCE UTILIZATION

Faced with rapidly depleting supplies of essential resources, what policy should we adopt? How can we radically change our concept of resources?

During the economic boom in the 1950s, America's consumer society became the ideal of modern life. But within two short decades economists and environmentalists realized that world cannot support limitless consumerism. The first step in reform was recycling of material. Metal resources are exhaustible: this does not mean that the metals themselves will disappear, but that they will be dispersed all over the world. If they can be reconsolidated these metals would again constitute a resource.

For example, an abandoned car, refrigerator or television set is usually disposed of as waste. However, if these items were processed they could be transformed into ore from which metal could be recovered and reused.

Today mainly chemical fertilizers are used in agriculture and the waste products are drained out to sea. This results in pollution. In the Tokugawa period fertilizer run-off was returned to the paddy fields and used again as fertilizer. If we can recycle materials in this way then resources will last much longer, defusing the threat of exhaustion.

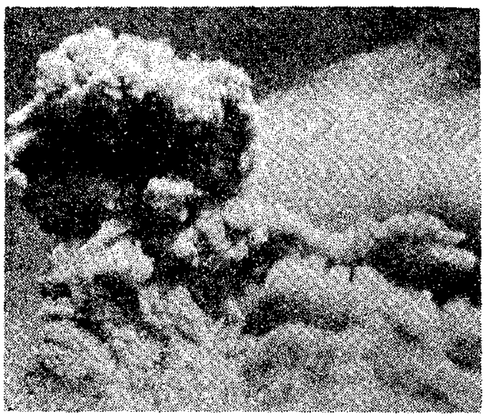
Our concepts of the availability of resources must also change. Resources are substances required for production of goods for our daily life; the same resources are not always required in the same quantities at all times.

For example, iron and aluminum are used as building materials, but building materials need not be metal. Timber and stone are good construction materials, too. Although metals may have certain advantages in building, other options should be considered so as to obtain the best use of our limited resources.

Once aware of the inevitable exhaustion of present resources, man must strive to change his habits and demands. At the UN Conference on Human Environment, in 1972, in Stockholm, this idea was emphasized and preservation of natural resources strongly recommended.

Chapter Four

Energy Revolution



Eruption of Sakurajima, Kago-shima, Aug. 27, 1967.

However strong the flames, and
However furious the holocaust,
Thy single breath
Shall put an end to it.
Even an iron man shall lose his strength,
And a spendthrift will come to dogs.

Prayer Book of Babylonia
"Wars of Gods", c. 2000 B.C.

RAPID INCREASE IN ENERGY CONSUMPTION

We do not know exactly when early man realized his ability to use tools nor when he discovered fire, but his ability to use wisely these gifts of nature set man apart from other creatures.

In ancient times the main source of energy was wood and the amount of energy available was barely sufficient. In the late eighteenth century, coal came into wide use, especially in England. By 1870 oil and by 1900 electricity from hydroelectric power were established sources of energy and the amount of energy consumed increased very rapidly.

Putnam conducted research on the amount of energy used. Using his survey as a reference, Table 3 shows the amount of energy consumed in the entire world by year and the type of energy resource.

The last column in the table shows the energy consumed per capita per annum. The same data, total energy consumed and energy consumed per person, are presented graphically in Fig. 6.

Both illustrations indicate that the world's energy consumption and per capita energy consumption increase exponentially. Since 1860 the total consumption of energy has increased ten times, that is, at a rate of 2.3% every year. Putnam's analysis

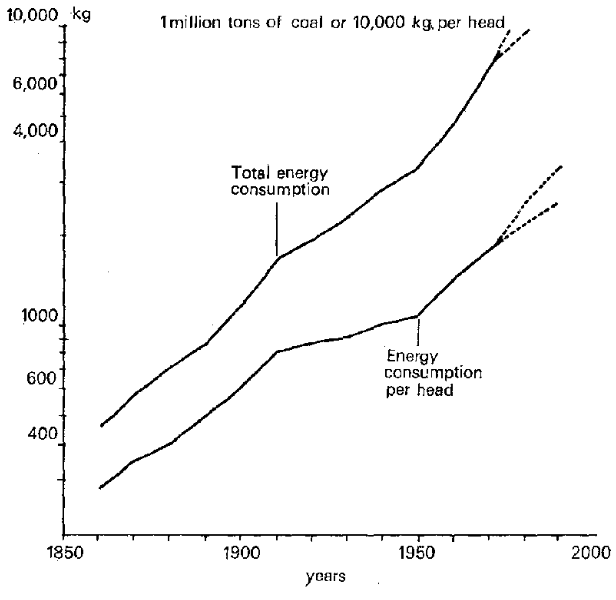


Fig. 6. World-wide changes in energy consumption.

ple, in April 1973, President Nixon expressed his concern over the supply of oil and advocated an energy conservation policy for all Americans.

We know that there are vast resources under the surface of the earth but they are not unlimited. If we use them with care they will last longer, but if we use them indiscriminately as we are doing now, these natural resources will soon be exhausted.

Coal stocks were estimated in 1965 to be 6700 billion tons, of which 3000 billion tons can be used economically. If we assume that world consumption is about 2.3 billion tons (1970), then coal stocks will run out in about 1300 years; if we assume that consumption is increasing by 1% every year, coal will last only for 260 years. With a 2% annual rate of increase, coal will disappear in only 160 years.

The future of petroleum is even darker. The estimated stock of this resource is increasing as surveys become more accurate. However, since consumption is increasing rapidly, experts feel petroleum will last for only another 30 years.

Table 4 shows the estimated stock of the resources and its yearly consumption. When we divide the total stock by yearly extraction, we get the number of years this resource can be used. The known value of petroleum has increased gradually but that value has begun to decline.

Our estimates are only approximates but if present trends continue and this resource is exhausted, within 30 years a serious crisis--a paucity of energy resources--will confront mankind.

Table 4. Crude oil reserves of the world and their life

Year	Stock in billion tons	Yearly consumption in billion tons	No. of years for which use is possible
1951	132	5.4	24
1955	221	7.2	31
1957	378	9.2	41
1959	420	10	42
1970	870	25	35

ATOMIC ENERGY--A PROMISING ALTERNATIVE

No easy solutions to the energy crisis readily present themselves. The problem must be approached from a scientific as well as technological viewpoint, since all aspects of political, economical and social life will be affected.

In order to increase energy output, some additional inputs and technological developments may be necessary. For example, the transport efficiency of the steam locomotive was 5-6% at first but later improved to 20% due to high temperature and high pressure techniques. In internal combustion engines and diesel engines, efficiency exceeded 30%. In metal smelting, the use of enormous blast furnaces increased efficiency greatly. With greater efficiency a substantial amount of energy can be saved.

Conservation of fuel is another aspect of efficient use of energy. For example, the amount of fuel needed for heating purposes differs according to the construction of a house. If the building is constructed to make the maximum use of sunlight or has good insulation, a great deal of energy can be saved.

Social patterns also affect energy consumption. In large cities, a great deal of energy is used daily as thousands of people commute to work. In the ideal city, where commuting distance is minimized, such wastage could be prevented. Such countermeasures to the energy shortage, however, are long range and vastly complicated.

Nonetheless, we must today begin to curtail our wasteful habits and derive the greatest benefits from the minimum resources. One way to do this is by recycling. To extract metal from ore and make that metal usable itself consumes a lot of energy. If we preserve the material carefully, natural energy can be saved and some degree of pollution will also be prevented.

Many efforts are underway to develop promising new energy resources. For example, the estimated amounts of available coal and petroleum increase annually. But, extraction methods must become more efficient in both cases. All the available resources cannot be exploited today; in most cases only 50% is exploitable. If coal can be transformed into a gaseous form or if oil can be extracted by adding water to it, extraction efficiency may increase.

The hope of future energy resources is, of course, atomic energy. At the beginning of World War II, in January 1939, two German scientists, Hahn and Straussmann, successfully carried heat in the earth's core, wind energy and the energy in tides or in lakes. Some of these have been tried, but we cannot expect to secure a large amount of energy through these resources.

IMPORTANT ASPECTS OF FUTURE POLICIES

Let us look at the energy problems which concern Japan. The changing pattern of energy utilization in Japan resembles the world pattern. Table 5 shows the changes in the supply of energy in Japan.

Total energy consumption has increased about 30 times during the past 100 years, while per capita consumption has gone up ten times. This is double the world average. Change in types of fuel used is the same as for the world and as of 1970, oil occupied the largest share with 65%, coal next with 12% and hydraulic power third with 7.5%.

One characteristic of energy consumption in Japan is that the use of hydraulic power is comparatively greater than throughout the world. This is due to favorable climatic and geographic conditions in Japan. Hydraulic power consumption is four times the world average where it is not even 2%.

Another important characteristic of energy consumption in Japan is this: in 1970 about 79% of the total energy used was from imported energy sources. In particular, 99.6% of the oil was imported. This was possible because of our good geographic location, economical transportation and the successful growth of the G.N.P. However, oil supplies are vulnerable to manmade and natural calamities so a steady supply of oil cannot be taken for granted.

Among the energy sources produced domestically, coal is the most abundant. Coal presents no problem to Japan. The estimated available amount of coal in 1965 was 19 billion tons. If we assume that 60% of this can be retrieved economically, then the usable amount comes to ten billion tons. The amount actually extracted every year is about 40 million tons, as of 1970. We anticipate no further increases in this amount; therefore, at this rate it can be used for 250 years.

The world's energy problem applies equally to Japan. When oil is exhausted in 30 years, civilization will face a crisis.

Reactions to this problem have been widely discussed all over the world. As Japan is not an oil producing country, the depletion of oil supplies will probably affect her earlier and

Table 5. Changes in the energy supply of Japan
(in units of 10,000 tons of coal fuel)

Year	Coal	Oil	Natural gas	Hydraulic power	Char-coal, Timber	Import		Total	Consump-tion per person, kg
						Coal	Oil		
1890	260	-	-	-	1258	-	-	1518	382
1900	656	-	-	-	1095	-	-	1751	400
1910	1380	45	-	2	1160	-	-	2587	525
1920	2519	50	4	111	1176	-	-	3860	692
1930	2696	45	5	451	1240	329	298	5064	789
1940	4834	48	7	818	2061	1089	603	9460	1318
1950	3395	51	9	1282	1112	330	216	6395	795
1955	3817	51	18	1631	1100	347	1058	8082	922
1960	4616	85	83	1999	766	901	3864	12314	1422
1965	4972	89	262	2680	386	1694	10480	20563	2040
1970	4470	102	340	2810	228	5095	24770	37815	3560

If we ignore the concord of natural resources, the ultimate consequence of this negligence will be barren land, indiscriminate deforestation, polluted rivers and probably the disfigurement of scenic beauty.

Lilienthal
The TVA

RAPID ECONOMIC DEVELOPMENT THROUGH ABUNDANT WATER RESOURCES

Water is a resource. But precipitated water is a more readily useful resource. Japan is surrounded by the sea. Abundant as sea water may be it can neither be used as drinking water nor for irrigation. Except in special cases, it cannot even be used for industry. After World War II, Japan achieved astonishing economic growth. One of the factors helping Japan to move into the second place in world G.N.P. was ample rainfall.

No living thing can survive without water. The amount of water available is a factor controlling life. In subtropical regions of the world there are vast deserts where almost no life exists. This is because there is very scanty rainfall and almost no water. If water could be supplied, the region might become very fruitful. The Aswan Dam of Egypt is one such effort in this direction.

The construction of a project such as the Aswan Dam was long an Egyptian dream. The dam can store about one-fourth the total precipitation per year over all of Japan. If this water is properly circulated about 800,000 ha, an area the size of Hokkaido, could be cultivated and ten billion kilowatts of electrical power, or the total generation of electricity with hydraulic power in Japan, could be generated. The completion of the first phase was inaugurated by Egyptian President Nasser on June 1, 1964.

There is an earlier example of such a dream. The Tennessee Valley Authority (TVA) Act signed by President Roosevelt of the United States provided for the construction of many dams on the Tennessee River for the development of the entire valley. The successful execution of this project was a landmark in American development in the twentieth century. According to a Chinese proverb, "One who rules the water rules the earth." Control over water is vital to man's life.

Interference in nature's systems inevitably leads to disruption in the natural cycle. Examples from such big projects as the Aswan Dam bear this out. Prior to the construction of the dam flooding of the Nile carried sand downstream. This sand contained minerals useful for agriculture. Since the construction of the dam, this process has stopped and cultivation has been affected. The mouth of the river now lacks support for the delta and erosion is becoming a problem. Nature maintains a balance which invariably is disturbed

120 BILLION TONS--THE LIMIT OF USABLE WATER

The amount of water precipitation is highly variable. There may be heavy rainfall in one year but a prolonged dry spell the next. Some of the precipitated water filters into the earth and, as it flows very slowly, requires little control. However, heavy rainfall may cause floods which result in serious damage. To avoid such damage rain water is usually allowed to run into a river and then flow out to sea. If it does not rain for a long time, a water scarcity develops. If all the water so wastefully forsaken can be purposefully stored on earth, it could be used during droughts. This is why so many dams were constructed in postwar Japan.

We shall now study water resources from a simple model in Sugawara Masoa's style. In this model we assume that:

1. In a valley there is always local precipitation of water and the average value of yearly precipitation is m.

2. After precipitation, the maximum amount of water filtering into the earth's surface or stored in dams is V which is the same as the maximum water deposition. For convenience, this amount is divided by the area of the valley to indicate the volume of water.

3. The proportion of usuable water to average water precipitation when water can be withdrawn from the river on a per hour basis is l. Thus $l \times m$ is the total amount of water which can be utilized.

4. Evaporation does not take place. After pinpointing a particular place or region, the actual amount of water deposits for past years can be calculated on these assumptions. Using this figure and then changing the value of l, the total amount of rainfall in a valley can also be calculated. In almost no case is the total water deposit in a valley zero. The ratio of V/m, the ratio of maximum water deposit to average water precipitation in a year, is shown in Table 7. Here zero water deposit means that the river flow disappears and water cannot be supplied.

In terms of dam construction and efficient utilization of land, it is impossible to have a larger water deposit in a valley. In Japan particularly land prices are high and it is difficult to find a site for dam construction. Hence a V/m greater than 0.5 is impossible. If we assume that the value of V/m for all of Japan is 0.5, then the amount of water necessary for the demand that can always be met is, as shown in Table 7, about 25-45% of the total water precipitation and an average of 30%. In this calculation, evaporation is assumed

Table 7. Relation between collected water V and utilization efficiency (V/m = maximum water collection ÷ average water precipitation)

Place	10	20	30	40	50%
Miyazaki	10	31	63	107	167
Hiroshima	18	41	74	114	154
Tokyo	17	37	62	94	135
Fukui	8	18	28	38	69
Abashiri	4	14	31	51	71

to be nil, but in reality it does occur. Therefore, the actual amount that can be utilized further decreases.

In Japan, the rivers are short and humidity is very high so evaporation is comparatively less than in continental rivers. For example, in the Nile in Egypt, about 97% of the total rainfall evaporates and only 3% flows into the sea. In the Yangtse in China, about 70% evaporates.

In Japanese rivers 20-30% is lost through evaporation and the remaining 70-80% flows into the sea. Yearly evaporation is about 320-480 mm. The total annual precipitation in Japan is 1600 mm. If we assume that this corresponds to an average of 400 mm, then the maximum water that can be utilized is 20-25% of the total precipitation.

Let us estimate this maximum in another way. According to Sonswhite, an American meteorologist, the relative values of water precipitation and losses due to evaporation in any area represent the climatic peculiarities of that region. Hence, evaporation loss means the total evaporation due to soil, grass, trees and so on. Based on the results of observations in the United States, he devised the following equation for the ratio of water precipitation (P) and evaporation loss (E):

$$\frac{P}{E} = \left(\frac{P}{5.0\ T + 62}\right)^{10/9}$$

Here P and E are the monthly figures in mm and T is temperature in centigrade (Celsius). The connection of P/E and the climate is shown in Table 8. If we assume that the average

Table 8. Climatic classification
(Sonswhite's equation)

Forest	P/E, %
Humid	
A. Rain forest	107 and above
B. Forest	53-106
C. Grass, Meadows	27-52
Nearly dry	
D. Steppe	13-26
Dry	
E. Desert	Below 12

monthly precipitation in Japan is 132 mm and the average temperature is 15°C, then according to the above equation P/E equals nearly 100% which in Table 8 corresponds to the forest climate.

For better accuracy calculations should be made for every month, but this result matches the climate of Japan, so his equation is also applicable to Japan.

According to the table, if a region has a P/E of 60%, it has a forest climate. When some of the precipitated water is deposited, even an 80% value of P/E apparently does not make any difference in the forest climate. We can even use 20% of the total precipitated water for special purposes. Based on these considerations, it seems that the maximum amount of usable water is about 20% of the total precipitation or about 120 billion tons or 1200 tons per person.

ENSURING WATER SUPPLY TO INDUSTRIES

So far we have considered only the amount of usable water available. We shall now look at the amount of water necessary for human life. Daily food preparation requires 25 l per person per day. Washing and cleaning requires another 50 l. Then water is required for transport, sprinkling, cooling and so on in increasing quantities as the standard of living improves. For example, in capital cities in 1920, the consumption of water was about 130 l per person per day, but by 1950 it had risen to 160-360 l and in 1970 it reached 430 l.

The average for the entire population of Japan is about 300 l per person per day. In a year this amounts to 110 tons and when this is multiplied by the population it becomes 11 billion tons which is about 9% of the amount of usable water.

Table 9 shows the level of water consumption in Japan during 1970 and in the United States during 1960. The figures are tentative and yet they highlight the problem of water utilization.

Table 9. The quantity of water consumed in Japan and the United States of America

Type of utilization	Japan (Billion tons/ year)	USA (Billion tons/ year)
For agriculture	375	2040
For industry	298	2040
For waterworks	91	350
Total	764	4430
% of total water precipitation	12.7	6.4

In 1960, the amount of water used in the United States was six times that used in Japan; the amount of water used for agriculture and industry was almost the same for both and was about six times that used for waterworks. In Japan, water used for agriculture was about 49% of the total consumption, the amount used for waterworks was about 26% that of the United States and the per capita amount used was about 50%.

The proportion of water consumption or utilization to the total amount of water precipitation is 12.7% for Japan and 6.4% for the United States. It appears then that utilization of water in Japan is much more advanced. In Japan, about 64% of the total usable water (which is a maximum of 20% of the precipitation water) is put to use.

The proportion of water used for irrigation is larger, but in absolute quantities it is one-fifth that of the United States. In a comparison of crop production it seems that water is used more efficiently in Japan.

In the development of water resources criteria from the USA cannot be applied to Japan. Independent research should be conducted for Japan.

We shall now look in more detail at water used for irrigation. Fields in Japan are irrigated by rain with the exception of rice fields where rain is insufficient and must be supplemented by water from rivers or lakes. In rice fields water is lost through evaporation or through seepage into the earth. Since the amount of water lost differs with climatic conditions and the condition of the field, no exact figures are available. However, we must allow for losses of 4-9 mm through evaporation and 10-15 mm through percolation per day, that is, a total of 15-25 mm per day or an average of 18 mm. If the 4 mm supplied by direct rain are subtracted, the required amount is 14 mm. If we multiply this by the entire area of rice fields all over Japan and assume that the life span of a rice plant is 100 days, the total required amount is 40 billion tons. This is 7% of the total water precipitation in Japan and 33% of the total usable water resources. Water for farms has not been considered except in special cases, but in the future we may have to do so. If the area covered by fields is assumed to be the same as that of rice fields and the water requirement is only one-fifth, then the total amount of water necessary is 48 billion tons.

Industry makes the next largest demands for water. In 1970, 29.3 billion tons were used by industry in Japan. This is much more than our requirements for daily life. For industrial purposes, in addition to the above, about 11.8 billion tons of sea water are used. This water is used for cooling, washing, processing products and so on. Here, depending on the type of industry, the amount consumed varies greatly. For example, in the steel industry 300 tons of water are consumed per ton of product. Of this 40-100 tons should be fresh water; the requirement of the paper pulp industry is 300-700 tons and for chemical complexes about 2000 tons.

Figure 7 shows the consumption patterns of the past. The use of sea water has not been included. After 1950, with the rapid economic growth of Japan, use of water for industry increased very rapidly. Industrial usage was two billion tons in 1950, but in 1970 it increased to 30 billion tons. This is similar to water use for agricultural purposes.

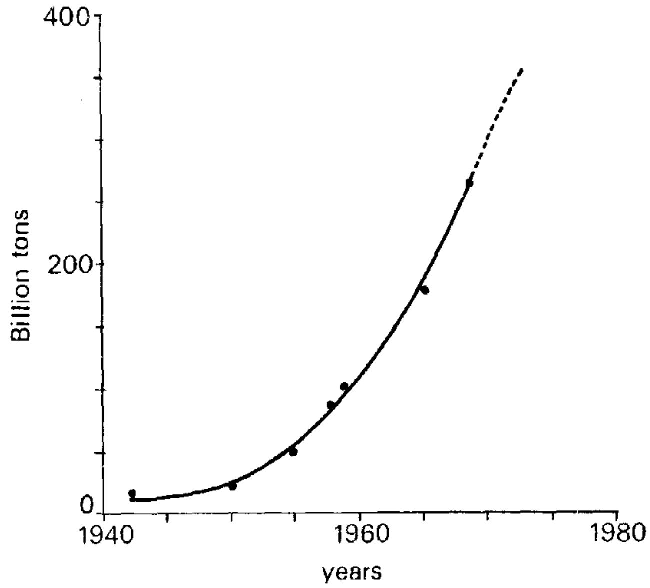
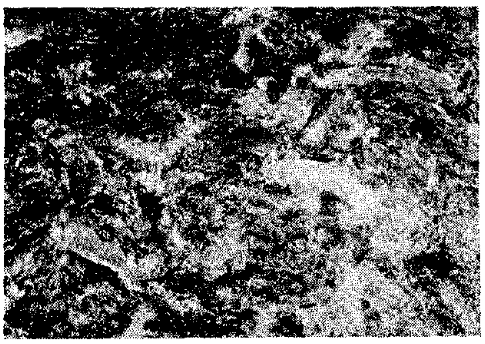


Fig. 7. Changes in the quantity of water used for industrial purposes.

These figures indicate that hereafter water supply to industry will be scarce and the cost of water for industrial uses will be very high. These costs may become a restraint on further economic growth. Among the proposals to solve this problem are these: connecting the various rivers by canals and using all water more effectively, recirculating the cooled water, purifying the water once used for industrial purposes and using it again or developing a technique for transforming sea water into fresh water. These suggestions must be considered for the future.

Chapter Six

Nonrenewable Biological Resources



Fishes crowding on feed (at Sasai, Saga Prefecture).

We should not forget the fact that every species sometime during its life receives a destructive blow from an enemy or from competition for the same land and the same food where it grows most.

Darwin
Origin of Species

FRESH APPRAISAL OF THE NUTRITION PROBLEM

"We think of manners only when the granaries are full and of the future only when the present hour provides ample food and clothing".

As this famous Chinese proverb suggests, food, clothing and shelter occupy vital positions in our lives. Society becomes unstable when food is scarce. After World War II, when food was very scarce and there were many delays in its distribution, thefts of food suddenly increased. Even during the recent shortage of soybeans when prices suddenly increased, there was unrest and confusion in the commercial community in the United States. In the past, food shortages always led to war.

Food available from living organisms is absolutely necessary for human existence. Before the time of Christ food, clothing and shelter were mainly obtained from living things. Today concrete, iron, timber and other substances are used as building materials and clothing is made from synthetic fibers. But this is not so with food. Food then appears to be the controlling factor in the population problem.

Food is the source of energy for human activities and at the same time a building material for human bodies. Not only the amount but the quality of food is important. The per capita consumption of food and changes in the average height of adults of 20 years of age are shown in Table 10. The average height increases every year. According to the data collected by sitologists, animal protein has a great bearing on the human organism. Consumption of animal protein at the end of the Meiji period was about three g per person per day, during the Taisho period it increased to seven g and today it has increased greatly to 34 g.

Correspondingly, the average height during Meiji was about 154 cms, during the Taisho period 157 cm and today it has increased to 160 cms. Particularly after World War II was there a distinct change both in the quality of food and in height. One difficulty in analyzing food is determining its quality. If we evaluate food only on the basis of calories, we find that corresponding to the increase in population even today, present caloric intake is adequate for the population. Chlorella is one aid in resolving this question.

Chlorella is a unicellular weed. During World War I, the German biologist Lindner proposed that this unicellular algae should be used as food. After World War II, Spore and Milner of the Carnegie Research Institute in the United States studied that proposal. Chlorella is easily cultivated. The cultivation solution containing inorganic salts is put into

Table 11. Per capita food consumption per year in different countries

Country	Cereal, kg	Roots, kg	Sugar, kg	Beans, kg	Meat, kg	Milk, kg	Fats, kg	Energy requirement, cal/day	Proteins		Year
									Animal, g	Total, g	
Japan	151	58	11	6	3	11	3	2220	4	61	1954/55
India	127	12	14	22	1	44	4	1850	6	50	1954/55
Burma	154	8	6	10	6	8	3	1990	10	68	1947/48
Egypt	189	8	13	9	11	55	4	2530	8	73	1953/54
Union of South Africa	153	19	37	2	43	88	6	2600	21	75	1954
Argentina	99	86	39	4	104	155	13	2840	33	94	1954
Turkey	202	31	9	9	16	30	5	2670	8	87	1953/56
Italy	147	49	17	7	20	100	13	2560	16	75	1955/56
W. Germany	96	158	27	2	47	170	25	2970	32	78	1955/56
U.K.	88	160	46	4	66	202	22	3210	38	84	1955/56
Switzerland	101	84	38	2	50	310	17	3100	33	92	1954/55
U.S.A.	70	46	40	4	81	236	20	3100	40	93	1955
Sweden	77	102	41	2	51	295	22	3030	42	85	1955/56
New Zealand	87	54	43	2	103	275	21	3375	49	102	1954
Australia	84	56	51	2	108	180	17	3160	42	88	1953/54

Table 12. Caloric value of various agricultural products per unit area (Rice = 100)

Agricultural products	Caloric value
Chlorella	1000
Sweet potatoes	160
Rice (water field rice)	100
Potatoes	84
Sugarcane	77
Barley	58
Maize	49
Carrots	49
Soybeans	45
Rice (upland/drying rice)	46
Apples	38
Spinach	19
Milk	9-15
Bamboo shoots	11
Pork	2-7.5
Beef	0.5-3

one-half of the present population could enjoy it. This is mainly because the staple food in Japan (as well as elsewhere in Asia) is rice.

Rice contains calories as well as proteins and as a food it has special qualities. Indeed one could live on rice and salt alone. No other food has this property. In Asia, the surplus population is a result of rice consumption or because they were cultivating rice, their population increased.

Fish is the major source of protein in Japan. But fishing differs from agricultural cultivation in that one must catch the resource that already exists in nature. Fishing methods have advanced greatly and deep sea fishing has also progressed. This has gradually increased the amount of catch--by 50% compared with prewar years. However, fishing has an uncertain future. Due to pollution and other disturbances, fishing has become more difficult. Deep sea fishing is an important supplement but each country is trying to expand its territorial waters for fishing. Whales are found only in the Southern Ocean and their population decreases year by year.

The amount of catch changes greatly depending on the condition of the sea. Variations in yearly catches are also great and over a long period of time a decrease has been noticeable. This presents an economic hardship to fishermen which is reflected in periodic shifts in fishing villages. Today marine industries have expanded and with multisided activities such as deep sea fishing, they are trying to overcome unfavorable conditions, but with little effect. Under such conditions we cannot expect fish to become a big source of protein.

In the future we might develop something for the sea corresponding to fertilizers in agriculture, something that increases plankton and fish resources. But first we need research on this subject. In another direction, the fish caught may be more effectively used through such facilities as cold storage. Such conservation will increase the relative amount of the catch.

Indigenous production of food in Japan today is insufficient and imports are increasing rapidly. For example, eggs are produced in Japan, but chicken feed is largely imported. Calculated on the basis of calories, according to the author's estimates from 1955 statistical tables, 89% calories were produced in Japan. However, this amount decreased in 1960 to 86%, in 1965 to 75% and in 1970 to 66%. Japan therefore cannot isolate itself from the rest of the world and in terms of food supply, economic conditions in other countries have a great impact on Japan. Changes in weather seriously affect agricultural production so weather in Japan and throughout the world must be carefully observed.

As the standard of living has risen with rapid economic growth, less importance has been given to the problem of food supply. However, we feel that this is the primary problem facing mankind in the near future.

PLENTIFUL RESOURCES FOR CLOTHING

Clothing is also an essential of human existence. During the Genji period, animal skin was used as clothing and later we mastered the art of weaving cloth from spun cotton. The fibers made from flax, cotton, silk and fur have been used for a long time.

In 1891, Chardonne, in France, dissolved plant fibers in chemicals and by passing them through small holes successfully created artificial silk. Various technological improvements followed and clothes soon began to be made from plant fibers.

In 1937 the Du Pont Company of the United States successfully made industrial nylon from coal, petroleum and natural gas; this product had better properties than the natural fiber. The uses of artificial fibers increased rapidly and when used as fishing nets, for example, artificial fibers surpassed natural fibers. Nonetheless, cotton today occupies a major portion of the market and will remain a major resource in the future, although the importance of artificial fibers will continue to expand.

We foresee no problem in the supply of raw materials for cloth in the future. Current economic analysis in the United States suggests that cloth is becoming a strong consumer item, but unlike food products it is not fully consumed daily. The yearly consumption of cloth changes according to the seasons and among different nations, but in Japan an average of 10 kg cloth per capita per year is used; consumption is similar in Europe.

This amount is about 8% of the yearly food consumption and about 2% that of coal production or the stock of wood. Cloth making entails various processes which makes it difficult to control its price. Expenditure on cloth accounts for 10% of a household budget, which is one-fourth the food cost. In terms of resources, however, no clothing shortage looms ahead.

JAPAN'S DIMINISHING FOREST RESOURCES

The forest is one of the principal life sustaining resources. About 100 years ago, wood was the major source of fuel for mankind and only recently have oil and coal become major fuels. However, geologically, oil and coal are derivatives of animal sources.

Although today building materials, utensils and other items are made of metal, timber is still an important resource, especially as a raw material for paper. Forests are the main sources for such materials, but efforts to plant trees on mountains and measures taken for flood control also contribute to the forested area. In Japan in 1970, the total forest area was 24.48 million ha of which 6.82 million ha, about 8%, was the forest area necessary to prevent land erosion, water evaporation, storms and other calamities or reserved for fish cultivation. Plant life has a major role too in transforming carbon dioxide into oxygen through photosynthesis.

Japan is blessed with rich forest resources. There are many mountains and the proportion of land covered by forests is large: about 68%. This is vast compared with that of other countries. A few thousand years ago Europe and China were probably also covered by forests but today their forest area is shrinking. In France the forested area is now 20%, in India 18%, and in China only 10%. Among the developed nations today, some have thick forests such as Finland with 69% forestation and Sweden with 53%. However, there is probably no nation with forests as thick as Japan.

Japan's climate and geographic conditions have encouraged the development of rich forests. Today houses are constructed of wood and wood products are widely used. The Sonswhite coefficient classifying the climates, that is, the ratio of precipitated water to evaporated water, also applies to forests. Table 13 presents this coefficient for several countries. If its value is high, the forest area also tends to increase. According to this coefficient, Japan could have larger forests. But from another point of view, the forest resources of Japan are insufficient. Per capita forest area is only 0.3 ha, one-fourth of the world average of 1.2 ha. By way of comparison, Canada and Australia have 22.5 ha and 19 ha per capita, respectively.

Table 13. Forest areas of various countries

Country	Proportion to the total land, %	Average per person, ha	Sonswhite coefficient
Finland	69	4.7	55
Japan	68	0.3	102
Norway	53	2.3	112
Sweden	53	2.9	46
Canada	45	22.5	93
Philippines	40	0.4	101
USSR	34	3.3	50
W. Germany	32	0.1	53
USA	29	1.5	53
Australia	27	19.0	37
France	20	0.2	51
India	18	0.1	39
China	10	0.1	52
World	29	1.2	–

Along with increase in population and economic growth, timber consumption is increasing very rapidly. Since domestic production cannot meet the demand, large quantities of timber are being imported. Table 14 shows the changing patterns of domestically produced and imported timber. The proportion of imports has increased greatly in recent years. In 1960 it was 8%, in 1965 24% and in 1970 53%. In 1972, because of the increasing demand for timber, prices soared

Table 14. Changes in the consumption of wood in Japan (in units of 10^6 m^3)

Year	Charcoal	Timber	Total	Amount imported
1900	51.3	9.7	61.0	-
1910	29.8	5.6	35.4	-
1920	32.6	12.0	44.6	-
1930	34.6	13.2	47.8	-
1940	59.3	30.5	89.8	-
1950	31.2	20.3	51.5	-
1955	28.4	42.8	71.2	2.1
1960	25.5	48.5	74.0	6.4
1965	12.4	50.4	62.8	20.2
1970	4.0	46.2	50.2	56.8

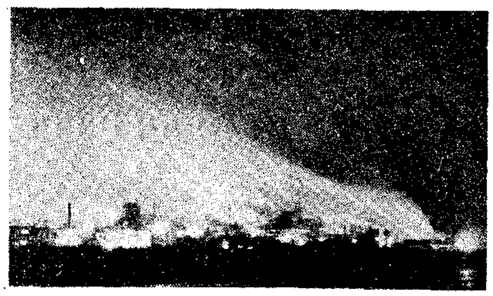
and procurement of timber became a major social problem. It is also a problem for trading companies and the simple explanation that importing is difficult is not convincing. The basic problem is that domestic production cannot meet the heavy pressure of demand.

It is very difficult to supplement imports with domestic production. In 1970 the forest area was 25.28 million ha, the volume of trees 1900 million m^3 and yearly growth 55.8 million m^3. The amount of trees consumed is shown in Table 14. In 1960, since the amount of growth improved, consumption reached 74 million m^3, but then decreased to 50.2 million m^3 in 1970. If we take this resource as of 1960 and try to meet the demand with only domestic production, then with 20 million m^3 timber being used every year, the total forest area will vanish within 100 years.

We cannot supply the total population with life-sustaining resources through domestic production. Hence even today a large amount is imported. If we decide to use only indigenous materials, then either the standard of living must fall or the population must decrease. From this perspective, too, Japan cannot isolate itself but must develop international contacts to help ensure survival.

Chapter Seven

Increasing Pollution



Winter: Smoke emitted by factories forms clouds, prevents snowing (Photo by Yamamoto)

Man is the creature of his environment, but at the same time he shapes it. The local environment has a direct relation with human survival and it creates a basis for intellectual, moral, social and psychological growth.

Stockholm declaration on the
human environment

THE EFFECT OF HUMAN ACTIVITIES ON POLLUTION

Pollution has raised its head as a black spot on affluence, posing a serious problem to human life. Everyday newspapers, radio and television carry reports on photochemical smog, cases of Minamata disease, paddy crops affected by cadmium, airplane noise and other aspects of pollution.

The problem of pollution is not a recent phenomenon. The word 'pollution' was used even in the Meiji period and according to the dictionary, it is defined as:

'A disaster caused by the activities of public and private industries which causes local people to suffer'.

A specific example is the famous case of ore poisoning in the copper mines of Ashio during the twentyfourth year of Meiji (1891). The farmers on the banks of the Watarase River registered their objections. As the smoke from the smelting furnace contained sulfur dioxide fumes, all the trees in the vicinity disappeared and the crops in the fields were seriously affected. Some of the population was forced to migrate to Hokkaido.

In Osaka the smoke emerging from factory chimneys polluted the air and endangered health. A preventive measure was passed in June 1932 in the form of the Smoke Prevention Act.

At that time, however, the main cause of pollution was big industry and damage was confined to small areas. Today the problem has become more acute. After the war, with scientific and technological advancements, man's activities have expanded enormously. The resulting pollution adds to the pollution from exhaust and noise from automobiles and from household waste. Industry is no longer solely responsible for pollution.

Pollution includes not only air pollution, but sea or river pollution from mercury and biological pollution from agrochemicals. Its severity increases all the time. Therefore, the very definition of pollution must be extended. Hanya Takahisa, in his book, has quoted the following passage from the discussions of the Conference on Human Environment as an explanation of the term pollution.

Pollution is a poisonous phenomenon which results from human activities and affects the general public or local sections of society. It affects human beings and animal life as well as plant and material production. But it is very difficult to prove the relationship between cause and effect and to determine the level at which it is affected.

As human activities flourish, pollution increases and as it spreads beyond regional limits, it affects the entire world. It was only in the late 1960s that the world became aware of the global scaie of pollution.

In late January 1967, President Johnson in his State of the Union Message to Congress gave special importance to the problem of pollution and the policies necessary for counteraction.

In Japan, the Bureau of Environment was formed in July 1971 to seriously consider countermeasures to pollution.

In June 1972, the UN arranged a conference in Stockholm on Human Environment. Although boycotted by the Soviet block, the problem received worldwide attention.

Pollution has become a focus because human activities have become so intense that they have begun to affect nature. At the beginning of this century, man started using chemical fuels such as coal and oil in very large quantities. In the post-war period pesticides such as DDT and BNC were used to exterminate pests. Man increased production and synthesized new materials such as vinyl and PCB (Poly Chloro Biphenyl), using them in huge amounts. In the process, vast quantities of waste materials were thrown into nature's lap.

Were the earth very large, all man's waste material might have returned to its original state through natural purification processes. Even if it did not return to its original form, it might have been dispersed throughout the world thereby diluting its concentration. Natural conditions might not have been spoiled. However, the earth does not have limitless powers of absorption and its present limits have become very clear.

LEGAL MEASURES TO PREVENT AIR POLLUTION

The consumption of chemical fuels (petrochemicals) in large quantities obviously pollutes the air. When a petrochemical is burnt, it releases into the air carbon dioxide, water, sulfur dioxide and other substances. If the moisture content of the air increases, rain or snow are precipitated. The proportion of moisture in the atmosphere is fairly constant with time. However, it is now suspected that the amount of carbon dioxide in the atmosphere is increasing. When the amount of carbon dioxide increases, its warming property causes the temperature of the atmosphere to increase. Some scientists believe that the continued warm winters in the post-war period are due to this factor. More details of the problem will be discussed later. However, photosynthesis of plants separates oxygen from carbon dioxide in the atmosphere leaving as a residue compounds of carbon. As a result, on a global geospherical scale, there is little danger of any appreciable change in its quantity. It is not particularly harmful to humans so there is no cause for alarm. However, since its quantity can be easily measured it is used as an indicator of pollution.

Those elements which seriously affect living things when petrochemical fuels are burnt are the oxides of sulfur and nitrogen. When there are strong winds they are distributed in the air and in diluted form they are not a threat but cause only a reversal in temperature. However, when the air is still, all the smoke from a chimney hangs low near the earth's surface and the amount of sulfur dioxide in the atmosphere increases. This results in increased cases of bronchitis and under severe conditions, even some deaths.

Such a disaster struck London in 1952 when, for the four days following December 5, the number of deaths exceeded 4000. Japan is fortunate in usually having strong winds so that severe temperature reversals in big cities or industrial belts are rare. There have been no casualties so far but because of the fumes of sulfur oxides from the petrochemical complex at Yokkaichi (Mie Prefecture), the number of patients suffering from asthma has rapidly increased. According to a 1963 survey, their number was ten times that of patients living in unpolluted air.

Man has some natural resistance to such harmful irritants. But this resistance differs from person to person and the degree of injury also depends on the time during which the harmful gas is inhaled.

In the United Kingdom, a survey was conducted to determine the relationship between the strength of sulfuric acid gas and the number of bronchitis patients and their mortality rate. It was found that there is a linear relationship between the two factors. When the level is about 0.2 ppm the effect is not immediate, whereas at 0.6 ppm the mortality rate rises to three times the normal rate. Ppm is a volume symbol representing parts per million.

Air pollution has many forms. On July 18, 1970, 50-60 girls from Rissho High School in the Suginami Ward of Tokyo found difficulty in breathing, felt dizzy and had pain in the eyes, throat and so on. They had to be taken to a hospital by ambulance. This was the first incident indicating the seriousness of petrochemical smog. The specific cause of this incident was never determined but it may have been the ozone-like gases generated when the compounds of nitrogen, hydrogen and carbon, emitted by automobile exhaust, reacted with sunlight. A similar phenomenon occurred in Los Angeles in the mid-1940s as related by Hegen, Schmitt and others.

To avoid this type of air pollution, engines must be designed so that harmful gases are not released. Either fuel with a lower sulfur content could be used or a special unit could be attached to prevent the dangerous gases exiting the exhaust. However, the prohibitive costs of such modifications deter industry and individuals from adopting them. Legal specifications must therefore be framed and efforts in this direction are in progress.

ACCUMULATION OF POLLUTANTS IN LIVING ORGANISMS

Agrochemicals, another factor in pollution, present a further threat to mankind. Agrochemicals were widely used in postwar Japan to exterminate insects and weeds. As a result, the harvest per 'Tan' increased rapidly bringing huge profits to agrobusiness. However, the consequences soon became apparent. There are various kinds of agrochemicals, but DDT and BCH are recognized all over the world as particularly harmful because of their organic properties. Since this matter is chemically stable when released in nature, it does not disintegrate, but passes through various media and enters the human body. Figure 8 shows those media in a block schematic diagram as proposed by Edward. Thus, when a chemical is sprayed on the farm, 90% of it enters the soil and very little is dissolved in water through which it can enter grass. Cows eat the grass and man eats the beef. Some of the toxin flows down the river and ultimately enters the sea. Here it enters the plankton. Fish feed on plankton and man eats fish. Some of it evaporates and is dispersed in the atmosphere, traveling long distances. These residues then fall on the earth or into the sea with rain water. The many varied paths of the toxins make their control very difficult.

Even though the amount of toxin may be very small in the water or atmosphere, when it enters the body of a living creature, various chemical actions cause it to accumulate. In some cases, such concentration increases by as much as some thousands of times. Hence, what was considered harmless in small quantities could cause severe pollution. For example, once an unusually large number of birds died in Tule Lake in northern California. Examination of their bodies revealed a case of poisoning due to organic salt class elements.

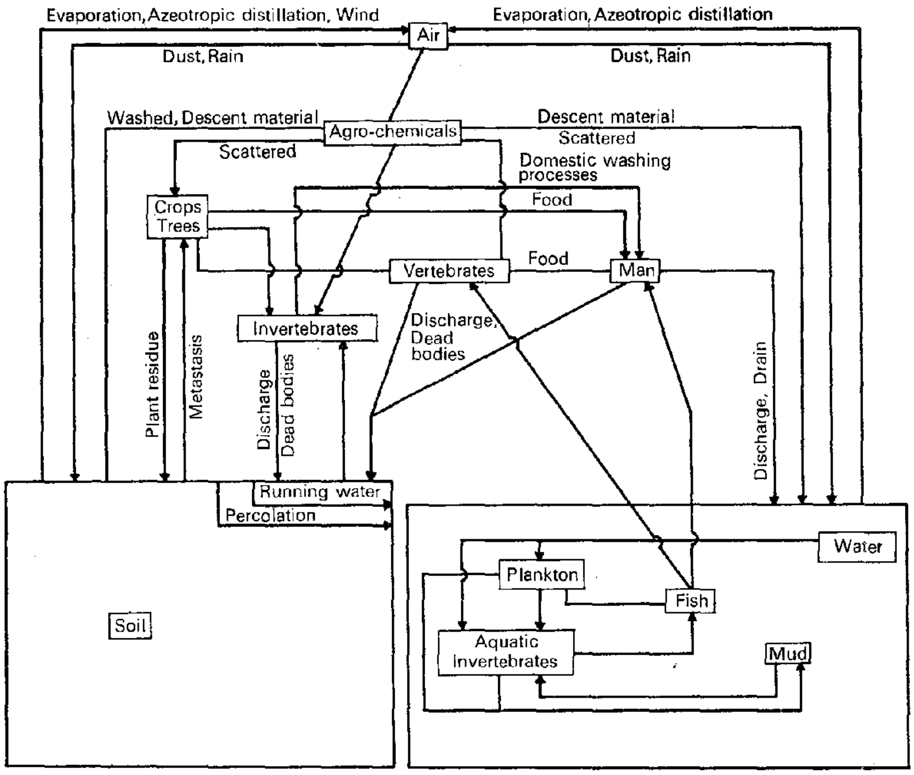


Fig. 8. Circulation of agrochemicals in an ecological system.

At that time the DDT dissolved in the lake water was an insignificant amount, 0.0006 ppm, but in the weeds it was 0.1-0.3 ppm, in dace fish in the lake it was 1 ppm and in birds such as the pelican or grebe the concentration was 60-80 ppm. Thus, the concentration in the weeds increased some hundred times, in the fish who grew on the weeds it increased 2000-3000 times and in birds who ate the fish it rose 100,000 times.

Minamata disease is a result of a similar phenomenon. Waste from compounds of mercury and methyl emitted by factories contaminate the sea water. These toxins enter the bodies of fish in the water and then the human or animal bodies which consume the fish in large quantities. Minamata disease is the result of poisoning by these toxins. So, while air pollution is serious, water pollution is a much worse threat as it is directly related to toxic concentrations in living organisms. Near Setonaikai (Inland Sea) in particular, an industrial belt spreads along the seashore and because of the huge wastes emitted the sea is becoming severely polluted. This has resulted in severe biological changes in marine life as changes in the yearly catch indicate. The haul of prawns and crabs has decreased severely. The catch in 1970 was just one-third that of 1960. Sardines and cuttlefish are increasing in numbers, but sea bream and others are decreasing.

The red tide phenomenon has been occurring more frequently in the Setonaikai region. Nishimura has studied this and Table 15 shows his findings on the frequency of occurrence of the red tide phenomenon in the Setonaikai region in different years. In the 1950s the frequency was low, during the 1960s it increased by 30-40 times and in the 1970s it attained a three digit figure.

The red tide phenomenon refers to conditions in which the plankton increases abnormally and the water therefore appears red. When this phenomenon occurs many fish die and shellfish are seriously affected. In the red tide phenomenon of July and August 1972, about 14 million yellowtails died near Harimanada and the total loss was valued at more than 6.8 billion yen. The frequent appearance of the red tide phenomenon is explained thus: as the development of the Setonaikai sea shore progressed, the waste with organic contents from pulp factories, breweries and rayon factories acted as nutriment for sea water. Plankton therefore increased.

PCB offers another interesting example. PCB was first synthesized in 1881. It is chemically stable, has good insulating

Table 15. The occurrence of the red tide phenomenon in the Setonaikai region

Year	Frequency
1950	4
1955	5
1960	18
1965	44
1967	48
1968	61
1969	67
1970	70
1971	136

properties and is nonflamable. Therefore, it is used widely as insulating oil, heat medium lubricating oil and in other ways. However, it pollutes the atmosphere causing death to birds. This pollution is found all over the world. Even the bodies of fin back whales found at the South Pole, so far from civilization, contained about 0.005 ppm PCB.

Man's many new activities have resulted in the creation of matter which never existed in nature; the resulting pollution has spread throughout the world. One indication of this is the annual change in the amount of lead found in the snow in Greenland, as shown in Fig. 9. Presently the lead content is increasing very rapidly. One reason may be that the lead from automobile exhaust is increasing. The quantity in the South Pole, far from civilized society, is only one-tenth.

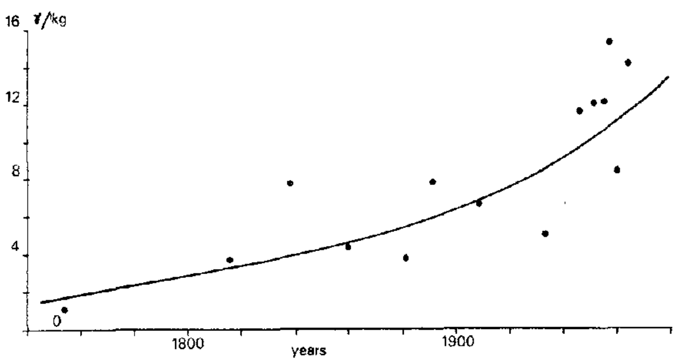


Fig. 9. Lead content in the snow in Greenland.

We see then that various toxins are dispersed throughout the world, crossing geographic barriers and polluting the atmosphere and oceans. While their speed is slow and present pollution is not severe, concentration of toxins will become severe within a few years. Even if we were to prevent all further emission of toxins, elimination of the present pollution will require many years. Immediate steps must be taken to prevent further pollution and the level of pollution must be watched constantly.

RADIOACTIVE POLLUTION CAUSES GENETIC DAMAGE

The threat to human race has other dimensions too. Large tankers ply the sea in greater numbers than ever before and when they meet with an accident, great amounts of oil spill onto the sea surface, causing heavy damage. On March

18, 1967 at 0900 hours the oil tanker *The Canion* got stranded off the northeast coast of Sicillian Island and all 117,000 tons of oil she was carrying reached the shores of Dover after flowing for many days. The severe damage resulted in the deaths of 15,000 to 16,000 birds and many fish. The government of the United Kingdom made every effort to minimize the losses, but after three days they had to blow up the stranded ship and burn all the oil.

In Japan in late November 1971, the tanker *Juliana* of Liberia got stranded off the Niigata coast because of seasonal winds. About 7200 kiloliters of oil spilled into the sea. The oil could not be burned as the fire would have been a great hazard to the nearby town. The Maritime Safety Agency controlled the area of damage by collecting the oil and spraying chemicals to dissolve it. However, this chemical contains a poison which kills fish so it really was hardly a solution at all.

Accidents aside, the exhaust oil released by ship pollutes the sea. When the oil spreads over the surface of the sea, evaporation decreases which may affect climatic conditions in general. Then, too, as the oxygen in the atmosphere cannot easily dissolve in the sea water, the ecological balance is affected.

Industrial and domestic wastes are also pollutants. Vinyl does not decompose easily so its waste products remain in the environment. Pollution from such wastes is a problem today and the treatment or processing of such waste is an important aspect for further research.

Pollution due to redioactivity is another modern day phenomenon. While it is not a daily pollutant, radioactivity is a sufficient threat to require close monitoring. Some natural radioactivity exists in the atmosphere and in the sea water, but in insignificant amounts. The main sources of radioactivity are manmade atomic explosions, the radioactivity released while generating electricity from atomic power and other emissions from atomic energy. On March 1, 1954, the United States conducted an experimental hydrogen explosion on the Bikini Atoll. As a result, the ship *Fukuryumaru X* operating 80 miles east caught fire. The resulting radioactivity caused atomic related diseases among the crew and one of them died.

In general, save some exceptions mentioned above, there are no zones exhibiting strong radioactivity. Radioactivity greatly affects heredity and it is known that the effect is cumulative.

When a nuclear explosion of a high performance megaton class is conducted, radioactive clouds spread over the entire world, causing calamities. Babies die in thousands because of congenital defects and four times as many children are born with deformities. This damage cannot be prevented if radioactivity is not controlled.

If the half-life of the radioactivity is short, these side-effects will rapidly diminish but in the case of strantium the half-life is long. Its chemical properties resemble calcium so if it enters the human organism it may collect in the bone marrow. This is of concern to all nations and the nuclear countries in particular are attempting to determine the consequences of nuclear explosions to prevent their increase. With the depletion of oil resources, however, the use of atomic power for the generation of electricity will surely increase. The radioactive ash must then be treated and more research on this subject is needed in the future.

Increasing pollution can thus be attributed to the fact that man demands a more affluent life, consumes various energy sources, produces materials not found in nature and throws them away irresponsibly.

Presently, the number of casualties due to pollution is much smaller than the number of deaths due to old age and disease. Pollution is a by-product arising from the realization of comforts for the majority. But the future presents serious problems. As the examples of PCB and other wastes indicate, most pollution is advancing without our knowledge, animal deaths due to pollution are increasing and new diseases raise their ugly heads.

Waste material must be processed to make it harmless before disposal and a place for disposal must be determined. Care must be taken that the resulting pollution does not spread elsewhere and that harmful materials do not enter the bodies of living organisms.

As a first step, industry should take the responsibility for the disposal of waste products of its manufacture and should ensure that pollution from industrial production is kept at a minimum. The nation must also set standards for the sources of pollution, such as exhaust or waste water, and must establish administrative guidelines to prevent pollution. In some cases it may even be necessary to stop production to prevent pollution. The ultimate source of pollution is the individual; this problem cannot be solved by industries or national policies. Unless each individual maintains a constant vigil and extends his complete cooperation, the task cannot be accomplished.

Chapter Eight

Ecology

Aerial view of orchards
(Spain)

What is right and what is wrong
I know not.
No reasons rule me.
I have bestowed life on thee,
And if I withdraw it,
I can confer it,
Even on a worm or another human being.

Turgnev's "Nature" in:
Collected Poems

THE UNITARY SYSTEM OF THE BIOLOGICAL WORLD

Man borrows various materials from nature for his survival. Many of these are derived from organic sources. Food consists mainly of animal products. Clothing is obtained from cotton, silk, fur and wool and timber is the main building material. Paper is made from wood pulp. A large portion of building material now in use is inorganic in nature and even the demand for clothes made of inorganic substances is increasing. But food cannot be derived from inorganic substances. Even energy sources such as coal and oil are organic although they appear to be inorganic.

Man cannot afford to destroy other living things for the many activities of these creatures are important to nature's balance. For example, oxygen, which comprises one-fifth of the earth's atmosphere, is made by plants breaking down carbon dioxide.

Living beings cannot survive alone. If all other life disappears, the human race will begin to diminish. Thus, all living things are part of one system and man, as a living being, is only one component of the system. In fact, nature itself, including the air, water and soil, comprises one system. This is apparent if we consider nature as a whole.

Energy is essential for the continuation of life on earth, but almost all energy comes from the sun. Sunlight enables plants to perform photosynthesis for growth, using carbon dioxide from the atmosphere and some microscopic particles dissolved in water. Herbivorous animals such as cows and horses depend on plants for nourishment. Man consumes plants and animals for nourishment. Many germs and parasites live within the human body. Weeds and plankton use sunlight and carbon dioxide or other forms of oxygen to grow in the sea and small fish feed on these. Small fish are consumed by big fish and when a big fish dies, its decay is highly nourishing for weeds and plankton. Thus, a unitary system is formed. A change in one part of the system affects the other living things too. Insignificant change causes no problem but change on a large scale destroys nature's balance, sometimes resulting in the extinction of a species.

There is a saying that when a storm comes, a barrel maker makes money*. This is true as far as ecology is con-

*When there is a storm, a lot of sand is scattered on the sea shore. If sand enters a person's eyes he becomes blind. A blind person, for his living, has to play

(contd.)

cerned and a good example is the effect on fisheries. Fish are very sensitive to changes in the natural conditions of the sea and if conditions change, the type and number of fish may change. During the Meiji period, herring were caught in large quantities near Hokkaido, but after the war the catch decreased greatly. In fact, the catch decreased by 90% and once flourishing fishing ports are now deserted.

EFFECT OF CLIMATE AND SUN SPOTS ON HERRING CATCHES

The dramatic decrease in the herring population is due to a great change in ecological conditions. However, it is not easy to pinpoint when and where this change occurred. One explanation is that with advances in fishing techniques, large numbers of herring were fished out in a short time and normal reproduction was impaired.

But this explanation is insufficient. If we study earlier records, we find that even in the past when fishing techniques were less developed, there were alternative periods of good and poor herring catches. Thus, overfishing is too simple an explanation for a poor catch. Fig. 10 shows the yearly catch of herring. In this graph, the solid line represents the statistical values and the dotted line the periods before 1870 based on a study of Uda Michitaka. This study determined the values on the basis of historical records and indicates that the cycle of good and poor catches recurs every few decades. This phenomenon is not confined to Japan, but also occurs in northern Europe. The cycle there is a similar and can be attributed to conditions of the sea.

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the Shamisen (a Japanese string instrument) which is made of cat's skin. Thus, the more blind persons, the more Shamisens required and the more cats which must be killed. With the scarcity of cats there is an increase in the rat population. Rats eat wood and wooden objects such as wooden barrels. In olden days, wooden barrels were used for storage of water, grain and other things. When they are gnawed by rats, there is a great demand for barrels and the barrel maker makes money. A storm thus brings in its wake a strange sequence of events.

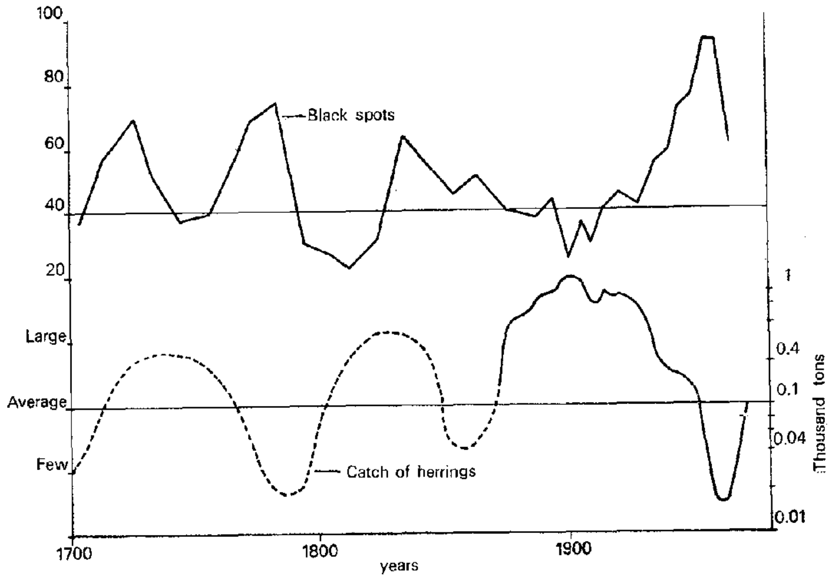


Fig. 10. Changes observed in the yearly catches of herring (1700-1970).

What are the reasons for periodic changes in the sea? In an area like the Setonaikai region where there are industrial effluents flowing into the sea, the nutrients in the sea water increase, plankton flourishes and the red tide phenomenon occurs resulting in the death of fish. But we do not know whether the magnitude of this process is great enough to cause changes in the condition of whole oceans and changes in the population of herring. These changes are also related to climatic changes. One interesting theory suggests that long term changes in solar black spots might be a cause.

We know that changes in solar black spots occur after intervals of 11 years. The population of Kenaga rats in Queensland, Australia and of the Clotinzo insect found in the Mississippi Valley in the United States changes at the same intervals. In Fig. 10, while drawing the curve for black spots, an average for ten years was taken to avoid the 11-year period. When this is compared with the curve for the herring catch we find that an inverse ratio exists between the two.

Although changes in the environment are certainly responsible for changes in the population of herring, reckless fishing also plays an important part. Human activities today have expanded vastly and their effect on the world's ecology can no longer be ignored.

Wild dogs and wolves are not seen in Japan today and the Japanese crested ibis or albatross has almost become extinct. The wide use of agrochemicals has controlled insects harmful to plants and pathogenic organisms. While harvests have increased, the birds which feed on these insects have starved and some birds died because of the chemicals dissolved in those insects. Phenomenon such as fall in the bird population is frequently experienced in our daily life.

We must be vigilant in maintaining the ecological balance. Man may eat various protein-containing foods but cannot produce those proteins within his body so he is dependent on other living organisms. If the animals serving as his source of protein vanish, man cannot survive. If the population of the animal world is too greatly reduced this may happen. Furthermore, man has started to synthesize materials that did not exist before and to introduce them to nature. The amount of synthetic matter is very small compared to natural matter, but in the long run it may spread throughout the world and accumulate in the bodies of living organisms. When man consumes them, he may contract diseases which may prove fatal. Minamata disease is an example of this, currently posing a social and political problem.

Medical science has become a double-edged sword in terms of cooperation between living organisms in the maintenance of an ecological balance. Postwar advances in antibiotics have conquered many of man's diseases. Today cancer is the main target of research. In man's struggle with germs and viruses, he is gradually winning. Mankind sees this as advantageous, but on a long term basis this may not be so.

The effect of disease control today on human beings is obviously good. As living conditions improve, even the weak will survive. However, as pathogenic organisms disappear, resistance to such germs is lowered. Today, we are still aware of recently eradicated diseases, but in the future mankind may be ignorant of epidemics.

Under such circumstances, if a person is exposed to germs and has no natural resistance, he may succumb to death. In one of Well's novels, a highly advanced people from Mars pays a surprise visit to the earth and falls prey to the germs here. At the end of the medieval period according to historical records some 30% of the population of Europe is reported to have died from the black plague resulting in a decrease in population.

MATHEMATICAL MODELS IN ECOLOGY

The word ecology is commonly used today. It is not a new word: it was coined by Heckel, a German biologist, around 1866 and refers to the science of shelter. More specifically, he defined this term as the science of the relationship between living beings and other forms of life and the environment. In 1895, in Japan, Miyoshi Manabu used the term 'plant ecology' and the study of ecology then began to advance. The content of the subject varies according to the scholar, but the above definition is adequate for our purposes.

Ecology is a general science and therefore differs from the analytical sciences so popular today. Perhaps this is the reason it has not been taken very seriously. Now that the problems of vanishing resources and pollution have become so evident, people recognize the importance of ecological studies.

In the study of ecology, we must observe the living conditions of different animals and how they change. It is also necessary to construct a mathematical model for analysis. At the beginning of the Showa period (1927) two mathematicians, Rotkar and Voltaire, considered the problem and constructed some theoretical equations. These equations can also be used to examine the effects of infectious diseases.

The mathematical nature of the equation makes it difficult to follow, but as it explains some important facts, we will discuss it here in simple terms.

Let us imagine change in the two populations of the earth. Let these two populations be N_1 and N_2. When no special factor is present, they increase by amount b_1 and b_2, respectively, per unit of time. If the population increases too much then procuring food becomes a problem and at a certain point the tendency to increase diminishes. Let this limiting point for the two populations be K_1 and K_2. Next, assume that these two types eat and are eaten; this also affects the population density. This is assumed to be proportional to their population and the corresponding coefficients are taken as α and β, respectively. With these assumptions, the changes in population per unit time of these two types, ΔN_1 and ΔN_2, can be obtained from the following equations:

$$\Delta N_1 = \frac{b_1 N_1 (K_1 - N_1 - \alpha N_2)}{K_1}$$

$$\Delta N_2 = \frac{b_2 N_2 (K_2 - N_2 - \beta N_1)}{K_2}$$

If we know the values of coefficients α and β, we can determine the initial populations $N_{1(0)}$ and $N_{2(0)}$. Then we can calculate how these populations change with time. Usually over a long period both values tend to remain constant. In this case the equation is reduced to:

$$N_1(K_1 - N_1 - \alpha N_2) = 0$$
$$N_2(K_2 - N_2 - \beta N_1) = 0$$

As a result, the populations at this instant, N_{1s} and N_{2s}, will be determined by the following equations:

$$N_{1s} = \frac{K_1 - \alpha K_2}{1 - \alpha\beta}$$
$$N_{2s} = \frac{K_2 - \beta K_1}{1 - \alpha\beta}$$

Here α and β represent the mutual interaction between two populations and can be positive as well as negative. Depending on these values, the actual change in the two populations may take different shape. The results of such mathematical calculations for different species are shown in Fig. 11.

As this graph shows, in illustration *a* there is no relation between the two species and both change independently. The result is the logistic curve which we find in population theory. That is, the growth rate increases at an exponential rate in the initial stages and then decreases suddenly when it reaches the saturation point.

Illustration *b* represents a case where species 1 survives by eating species 2 as its food. As species 2 is consumed by species 1, its population decreases. As an initial condition we assume that very few species of type 1 exist and the population of type 2 is the one that can develop by a natural balance. In this case, species 1 increases rapidly at first and species 2 declines as it is consumed by species 1. However, at a certain point, the populations reach a balance and thereafter exist harmoniously.

Eventually, both values hover around this basic value because if species 1 overconsumes species 2, then its source of food is reduced and the population decreases. When this happens species 2 shows an increase.

The only difference between illustrations *b* and *c* is that in *c* species 1 consumes species 2 in addition to other existing foods. In this case, both species 1 and 2 increase exponentially at the beginning and at a certain stage the increase is very rapid. It then reaches a maximum and starts falling. Species

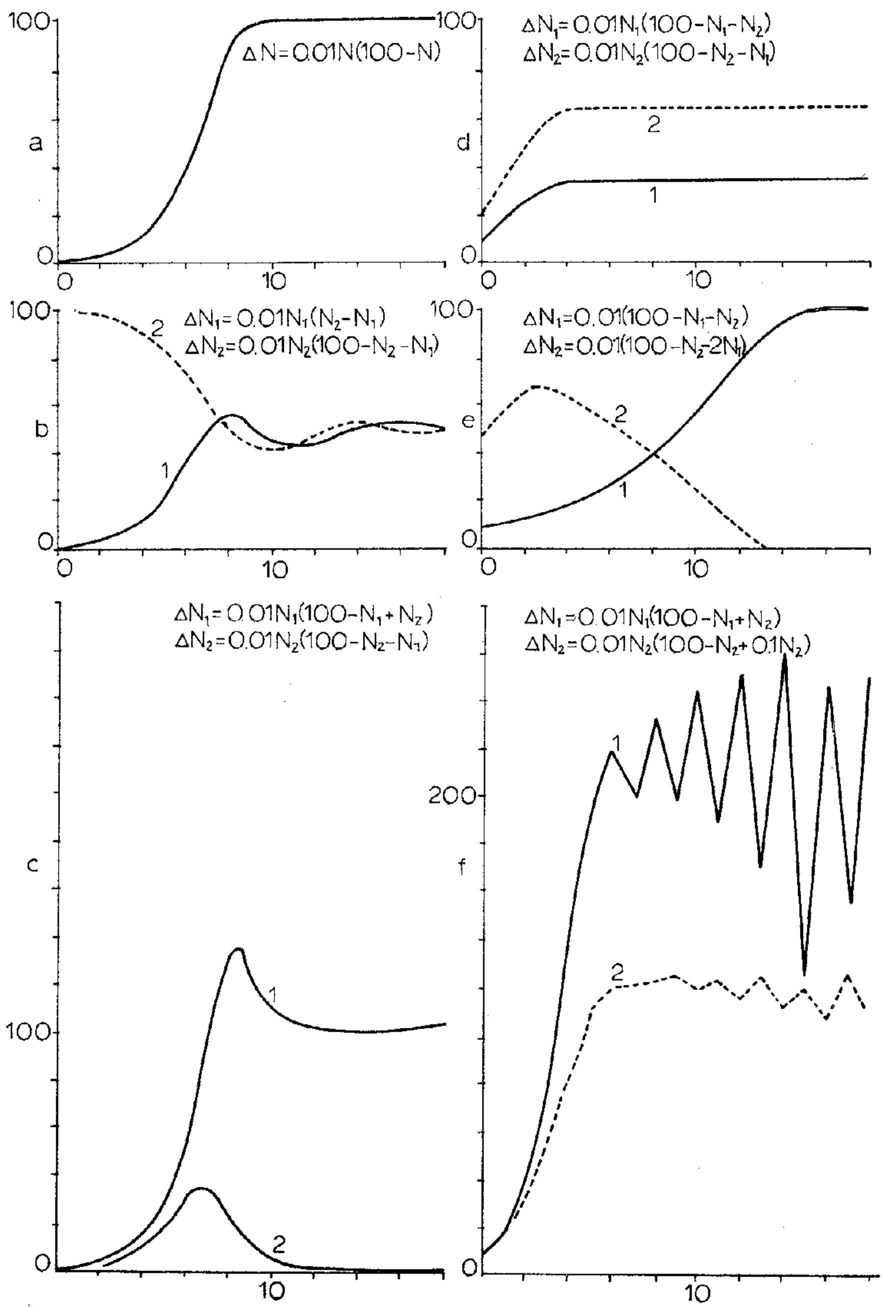


Fig. 11. Model showing population changes in two biosystems.

1 declines gradually and reaches an equilibrium, but species 2 continues to decrease gradually and ultimately becomes extinct. In this case, if the other food necessary for the survival of species 1 is also insufficient, then species 2 also reaches an equilibrium instead of vanishing completely.

The case in which both species 1 and species 2 affect each other in the same way is shown in illustration *d*. Here, both increase or decrease in proportion to their initial population and eventually reach a constant level.

Illustration *e* represents a case in which species 1 and species 2 affect each other adversely with the effect on 2 being greater. As a result, species 2 decreases and ultimately disappears.

The case in which each affects the other in a favorable way is shown in illustration *f*. Under these circumstances both species increase rapidly and the equilibrium value is much greater than when they are independent of each other (Fig. 11 *a*). Fig. 11 indicates that the change in period 2 is very prominent. This is because the time difference was great in the calculations. Had it been smaller, the changes would have been smoother. In fact, there is some change in the environment each year and if we take this time frame as the basic unit of analysis, this phenomenon may actually be observed, making the equation a representation of fact.

We have discussed here only extreme cases, but even in such simple models multiple factors must be considered. In actual life there are many more factors operating and conditions are very complex. If we construct a model where each of these factors is accommodated and if we use proper coefficients, the current situation is clearly stated and we may even predict what the situation will be in the future. For example, the results expressed in Club of Rome Report correspond to case *c* where species 1 represents the human race and species 2 represents food.

Chapter Nine

Weather and Social Phenomena

The great famine of Nigeria, Africa (June, 1973).

Fundamentally, climate is eternal. At the same time it passes through age-old patterns. We are bound to refer to it. We can't just ignore it.

Watsuji Tetsuro
Climate

THE RELATIONSHIP BETWEEN ACCIDENTAL DEATHS AND HIGH TEMPERATURES

A few years ago Hanchinton, an American, wrote a book entitled *Climate and Civilization*. He suggested that when climate is favorable, civilization flourishes and that changes in climatic conditions result in shifts in the center of civilization. This view has been expressed by many others and there have been many refutations too. A flourishing civilization can be defined as the sum total of human capabilities and however good the natural conditions may be, a civilization cannot evolve without the development of human capabilities. Even when natural conditions are unfavorable, man can marshall his resources and build a new civilization.

While civilization is the creation of man, even today man cannot overcome many of nature's obstacles. Indeed differences in natural environments and their changes greatly affect our lives and influence the life styles of different countries, their national characteristics, industries and so on.

Let us consider Japan. Japan is an island country extending north and south between the Eurasian continent and the Pacific Ocean. She is in a low pressure belt with complex weather variations and receives heavy rainfall. Japan is in the subtropical region and has four distinct seasons. The summer is hot and humid with seasonal winds, while the winter is dry and cold with heavy snowfall in the coastal areas.

The climatic situation is ideal. Because of abundant water there are wild forests and favorable conditions for the cultivation of rice. Because of the variety of climatic conditions, there is a large variety of vegetation and industries can thrive almost anywhere. This is why more than 100 million people can live in such a small country.

On the other hand, storms and typhoons occur regularly in Japan. During the rainy season there are heavy rainfalls and occasionally severe earthquakes. Since most houses are made of wood, there is a great fire hazard. Some people rightly feel that wooden houses are dangerous because of their inflammability.

Watsugi Tetsuro suggests that these characteristics of the country are reflected in the character of the Japanese people: they are very courteous and docile, but at the same time very sensitive, nervous and fatalistic by temperament.

They have a dual personality. They are quiet, but at the same time have a belligerent spirit. This corresponds to the weather which changes frequently. Seasonal changes also bring about changes in mood. The climate is favorable but at the same time there are unpleasant features such as typhoons and excessive rain. This is reflected in the dual personality of the Japanese people. Refutations of this viewpoint suggest that this completely ignores the life style of the people and oversimplifies the matter. However, there is some validity in the proposition.

These observations pertain mainly to climate, but daily changes in weather also affect our moods. If the weather is good, one feels comfortable. When the skies are clear, one feels like going out, but if it is raining, one prefers to stay at home. If we have typical weather in May, when people go out hiking, the temperature is above average and the weather is good.

Such activities have a social basis and are not due to weather, but they cannot be independent of the weather either. If it is raining such outdoor activities might not take place. Furthermore, more accidents occur on warm days especially during the summer. More accident casualties occur during years when the temperature is above average. Thus, we can say that temperature affects the mood of the people.

Climatic conditions also have a bearing on health. When a weather front approaches, mental illnesses become more severe and cases of high blood pressure increase. When weather has shifting high pressure, cases of asthma increase. The number of deaths due to old age increase in the winter, particularly when a cold front is passing.

Figure 12 is based on the distribution of pressure at the time and place of death of some 16 famous personalities. (The figures in the diagram indicate the month in which the death occurred.) The data appear to be one system of pressure distribution. The number of deaths is very small in high pressure belts while after a cold front, when temperatures drop, the number increases. This model uses a weather diagram, but daily changes in weather also support this conclusion.

THE INVERSE RELATION OF MARKET PRICES AND AMOUNT OF RAINFALL

Climatic conditions, especially temperature and rainfall, also affect clothing, food and housing conditions. In tropical regions food, clothing and housing can be obtained at low cost, but in cold regions their importance increases, resulting in higher prices. Table 16 shows the per capita calories consumed per day in various countries and the average tempera-

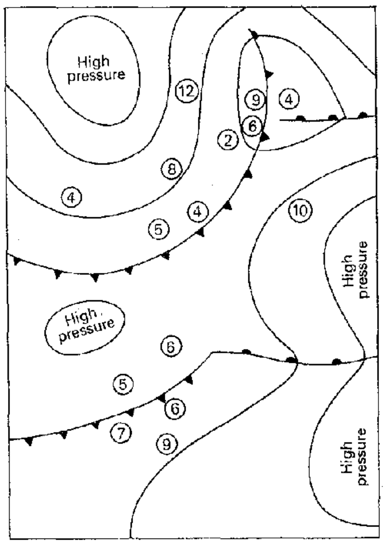


Fig. 12. The distribution of atmospheric pressure at the time of death of some famous personalities.

ture in those countries. Calorie intake also depends on the prosperity of a nation. In countries like the USA, calorie intake is much greater compared to countries with similar average temperatures, while in places like India it is lower. Nonetheless, nations with a high average temperature generally consume fewer calories.

The consumption of proteins has also been given for reference and in warm regions the consumption is relatively smaller. This also applies to Japan and is illustrated in Fig. 13 with 1969 prices from different parts of Japan. The graph compares the cost of light and fuel, food and housing with the average temperature of that region. Of course, the cost of living is not controlled only by weather conditions, but by factors such as custom, standard of living and so on. Such data are complex but the costs of light and fuel are clearly lower when higher temperatures prevail.

Food and housing costs in big cities such as Tokyo, Osaka, Yokohama and Nagoya are relatively high and vary according to cultural life. Nonetheless when the temperature is low, costs tend to increase.

It is interesting that costs and temperatures are related linearly on the graph and, if we extend the graph further,

Table 16. The temperature and per capita calorie intake per day in various countries (1967-1968)

Countries	Temperature, °C	Calories	Proteins, g
Philippines	27	2000	51
India	25	1810	45
Brazil	25	2690	66
Mexico	23	2550	66
UAR	22	2810	81
Australia	21	3120	91
Italy	16	2860	85
Spain	16	2790	82
Japan	14	2449	75
China	14	2115*	–
Argentina	13	2920	88
USA	11	3200	96
France	11	3100	101
UK	9	3150	88
W. Germany	9	2910	81
Switzerland	9	3170	88
Sweden	6	2850	80
Norway	4	2950	81
Canada	0	3180	95

*Data for the year 1948.

theoretically all of them will become zero when the temperature reaches 39°C. The temperature of the human body is 37°C so when the atmospheric temperature reaches that level, no special efforts are required to maintain body temperature. Therefore, neither clothing nor heating is essential and hence more food and elaborate housing are also not required.

The quantity of rainfall greatly affects our life. In deserts where rainfall is scarce, animals lead a hard existence and sometimes even plants do not grow. Japan has heavy rainfall and crises due to drought are rare, but flood damage is frequent.

The effect of rainfall on our daily life is reflected in our activities, but economic considerations also play an important role. While we may postpone outdoor activities on a rainy day, the weather alone does not determine man's activities.

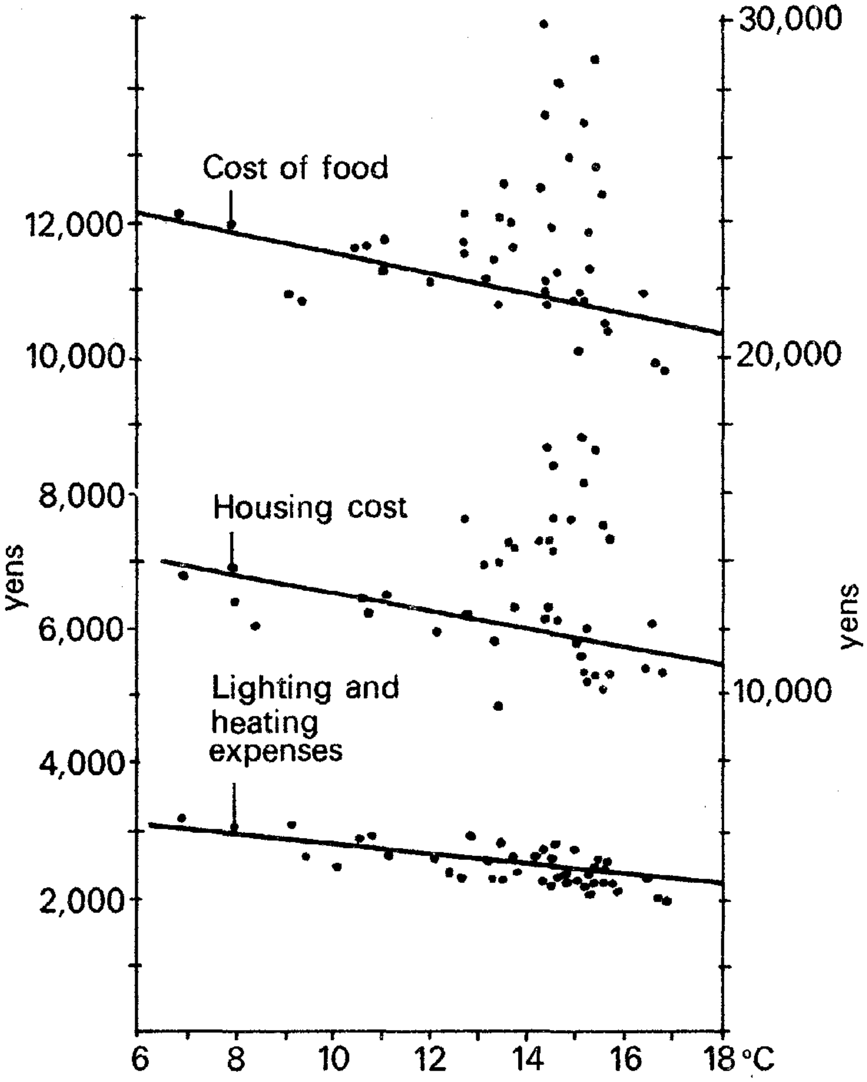


Fig. 13. The relation of atmospheric temperature to the average cost of living per person per month.

Economic and social conditions play an important role, more so as economic growth spirals. To some extent weather conditions are irrelevant and their effect is neutralized. If we compare the transport of persons and cargo in Japan with the figures of the previous year, then Fig. 14 can be drawn to correlate this with the amount of rainfall. As the figure shows, when the quantity of rainfall increases transport tends to decrease. Statistically, if the rainfall increases by 10% then transport decreases by 10%.

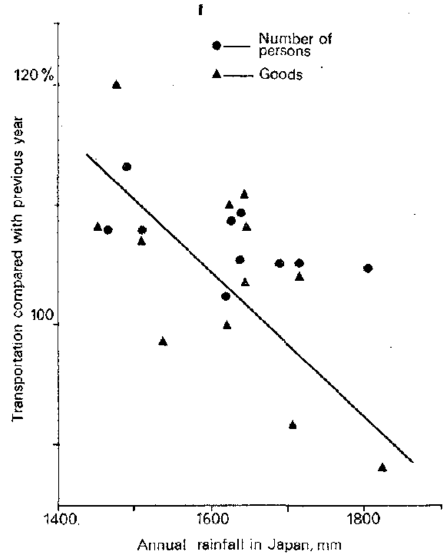


Fig. 14. Transport and amount of rainfall.

In reference to our prosperous barrel maker, we see that in economics, this axiom fits exceptionally well. The effects of rainfall are very apparent in price levels. Human factors are also important in determining prices but when prices are stable, the effect of rainfall becomes clear. If the amount of rainfall decreases by 10%, then prices rise by about 7%. When rainfall increases, the movement of materials slackens, thereby increasing stockpiles.

THE EFFECT OF ATMOSPHERIC CONDITIONS ON THE RICE HARVEST

Climatic conditions affect our daily life to a great extent. Agriculture is particularly vulnerable to weather conditions and the yearly harvest varies greatly with the weather. As an example, we will examine the relationship between the production of rice, the staple food of Japan, and the temperature.

The most important factor in the rice harvest is the temperature during the summer. If the summer temperature is below average, the paddy yield drops. Fig. 15 compares paddy yield and average yearly temperatures in Japan and reveals a close relationship. On the other hand, rice production is increasing with new developments in farming techniques: it has more than doubled during the last few decades. Therefore, the effect of temperature variation is not so severe, but we cannot deny that there is some effect. The relationship between paddy yield and weather is complex and if the average temperature changes during the germination period, the production also changes.

In western Japan the effect of changes in rainfall has been greater than the effect of changes in temperature. But in a general survey, we find that there is a good correspondence between the temperature and the paddy yield. If the average temperature changes by one degree, there is a variation in yield of about 30%.

Severe changes in climate seriously affect agricultural production. If such abnormal weather continues, a scarcity of food will result which will greatly affect society. For example, in the Tokugawa period when rice was the center of the economy, there were three droughts during the reign of Emperors Kyoho, Tenmei and Tempo. The poor harvests led to discontent among the masses.

As the poor harvests continued there were many starvation deaths and the population decreased. While neither agricultural nor transport facilities were as developed as they are today, we should not overlook the fact that this period was called a miniature glacial epoch and summers were cool.

Today the standard of living is much higher and the quality of life very different from that of the Tokugawa period. Nonetheless, two years after a poor harvest, the population rate shows a decline. The population growth rate and years of poor harvest are shown in Fig. 16. Some eight examples have been chosen after the Meiji period, when Japan started taking a regular census. The figures are calculated by taking the year of harvest as the reference point and averaging the rate of population growth for a few years before and after.

Figure 16 clearly shows that the rate of population growth decreases severely two years after a poor harvest. In this chart two years of poor harvests, 1941 and 1945, have not been included because of the effects of war.

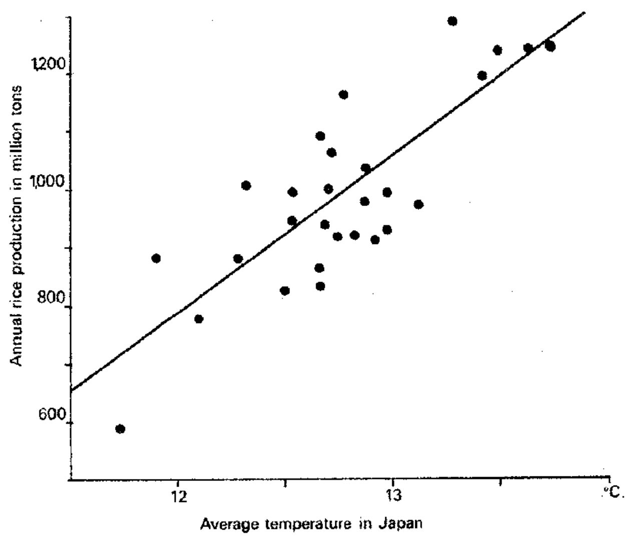


Fig. 15. The relationship between atmospheric temperature and rice production.

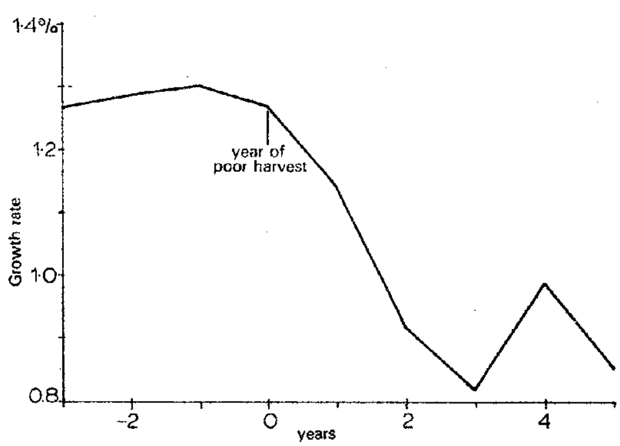


Fig. 16. Years of poo harvest and the rate of population increase.

Hanchinton feels that changes in climate have affected world history. For example, the second century A.D. was the golden period of the Roman Empire. The climate was very favorable, permitting good harvests year after year. In the fourth century rainfall was scanty, however, and because of poor harvests, nomadic tribes moved southward in large numbers searching for better land. This was the great Germanic migration. As a result, the Roman Empire weakened and was divided into east and west. The western Roman Empire ended in 476 A.D. That was a turbulent period for China, also, and there was an invasion of nomadic tribes for similar reasons. During the eighth century there was good weather all over the world. This was the golden period of Saracenic culture, while in China the Tang culture was at its peak. In Japan it was the beginning of the Nara period and the golden age of Tempyo art.

Between the thirteenth and the fifteenth centuries the weather was bad and there was a record number of glaciers and icebergs in the Atlantic Ocean. Poor harvests followed and the civilized world was again attacked.

In 1204, Genghis Khan united Mongolia and migration of peoples began again. In 1279, the southern Sung dynasty was taken over by the Mongols. This was at the end of the Kamakura Shogunate and Japan had to fight the Mongolian army in 1274 and 1281.

Climatic conditions and human life are closely related. Dry regions in particular are sensitive to the amount of rainfall and society may be very deeply affected by changes in precipitation. Japan generally enjoys heavy rainfall and long term changes have little effect. However, temperature changes affect Japan seriously. Man reacts to temperature change by employing either cooling or warming devices. Daily activities are determined by weather as well as by other factors. However, when we consider yearly averages for Japan, we find that climatic conditions greatly affect society and may affect future society even more.

A MODEL FOR THE IMPACT OF ATMOSPHERIC CHANGES ON THE SUPPLY AND DEMAND FOR RICE

The availability of food has recently been the object of great concern in our society. Advances in techniques of rice cultivation and changes in food habits have resulted in increased rice production and consumption, but the stocks have also increased causing a deficit in the food budget so that a policy of lower production was adopted.

Today, three years later, because of abnormal weather conditions all over the world, the stocks of rice have greatly dwindled so the agriculture policy must be reversed. Here we have another effect of climate on harvest. In some years rice production exceeds the amount consumed, but sometimes food is insufficient. To counter this we have to create buffer stocks and production planning sometimes must be revised.

Food is essential for man's existence and demands for food must be met. Therefore, we must study the differences in production and consumption and ways adjustments can be made. We present below a simple model and a mathematical expression of this problem.

Let us consider an example based on rice. Because weather varies, the harvest is sometimes good and sometimes bad. With only short term change, stocks will vary only slightly. If low temperatures continue for several years, the resulting poor harvests will lead to shortages and the stocks will be depleted causing a food crisis. If weather continues to be favorable, production will exceed consumption every year and the stocks will increase, posing a problem of preservation.

Since rice production must be controlled, studying the initial stocks for each year we can plan the next year's production. However, if we consider only the stocks and apply strict controls, then there may be heavy pressure on the supply. If the control is too loose, we may have enormous surpluses. We must work this mathematically on a simple mathematical model.

We produce rice every year and consume it. If production is greater than consumption, the surplus goes into the warehouse. If it is insufficient, rice is withdrawn from storage to meet the demand. The consumption of rice is thought to be controlled by the size of the population as well as by the average yearly temperature. Yearly production is determined by a production plan and the average temperature of that year. Production is planned by considering average consumption over a long period and the present stocks. The excess production is pooled into warehouses and an insufficient amount is supplemented from these stocks.

Let S represent the amount of rice in stocks, W the average consumption in a year and P the production. Then the difference between production and consumption will be given by changes in stock ΔS. This explains the first equation in Table 17. ΔS is the difference in stocks during the year. Consumption (W) is determined by the population and the weather during the year, while production is determined by the planned production (P_p) and the weather during the year. We assume that population is constant and if the temperature difference during the year is assumed to be θ, then the amounts of production and consumption are shown by the second and third equations, respectively, of Table 17. Here a and b are proportional coefficients. Equation 2 indicates that if the temperature is higher than expected, production is greater than planned, whereas equation 3 indicates that if the temperature is lower than anticipated, the consumption is greater.

For a satisfactory supply of rice, the production should be planned so that there will be neither shortages nor exces-

Table 17. Model indicating rice supply

1. $\Delta S = P - W$	Change in stock
2. $P = P_p (1 + a\theta) = P_p + W_s a\theta$	Production per year
3. $W = W_s (1 - b\theta)$	Consumption per year
4. $P_p = P_s + \alpha (S_s - S)$	Planned production at the beginning of the year
5. $S_s = W_s (1 + K)$	Standard stocks at the beginning of the year
6. $P_s = W_s = P_{p_s}$	
7. $\sigma_W = b W_s \sigma_\theta$	
8. $\sigma P_p = \sqrt{\frac{\alpha}{2 - \alpha}} (a + b) W_s \sigma_\theta$	
9. $\sigma_p = \left\{ \frac{\alpha}{2 - \alpha} (a + b)^2 + a^2 \right\}^{\frac{1}{2}} W_s \sigma_\theta$	
10. $\sigma_S = \frac{(a + b) W_s \sigma_\theta}{\sqrt{\alpha (2 - \alpha)}}$	
11. $S_z = S_1 (1 - \alpha) - \alpha (1 + K) W_s + W_s \sigma (a + b)$	

sive stocks. To determine the planned production (P_p) at the beginning of the year, stock (S) should also be considered. Equation 4 in Table 17 includes this. P_s is the value of planned production, W_S corresponds to consumption determined by population, S_s is the stocks at the beginning of the year. Considering changes in rice production and consumption, a certain amount is added to the standard consumption (W_s) making equation 5.

K is the constant, indicating the amount of redundancy. Again, α in equation 4 is a parameter indicating the level to which the present stocks should be considered while determining planned production.

Using these relations, the initial stocks and the temperature difference during the year we can calculate the planned production of the next year, the actual production, consumption, stocks and so on, numerically. If the standard deviation of θ, which indicates changes in yearly temperature, is taken as σ_θ then after by-passing the intermediate steps, equations 6 and 7 can be obtained. Here equation 6 shows that standard production, consumption and planned production are equal. σ_W is the standard deviation for yearly production, σP_p is the standard deviation for planned production, σ_p is the standard deviation in yearly production and σ_S is the standard deviation of the stocks. Table 17 does not mention it but the stock (S) and the planned production (P_p) are not statistically independent but have a relationship expressed by $(1 - \alpha)^n$.

If production, stocks and consumption of rice follow this formula, we will have the correct amount of rice. However, because of the multiple factors involved, there will be inevitable discrepancies. For example, changes in stocks and planned production have a phase difference of one year. If the stocks increase, prices will come down and rice will be surplus. If we decide to reduce production there will be unemployment among farmers. If the stocks shrink and the production target is raised, the people required to execute the policy and production of fertilizers and chemicals may create obstacles. In other words, changes in stocks cause rice prices to change and changes in production target cause changes in agricultural labor requirements. This is reflected in recessions and booms.

Stocks and production targets do not necessarily change in the same way, but according to the parameter α. For example, changes in yearly stocks are given in equation 10 in Table 17 and vary according to α. Changes in production targets are given in equation 8 and change according to α. α is a quantity that can be controlled by man. The calculated values of coefficients in equations 8 and 10 when α is changed are presented in Table 18. Examining this, we find that as α approaches zero, changes in production targets become smaller, but the stocks change greatly. If α increases too much, then changes in production targets become greater but changes in production reduce. It is minimum at one and as α increases and reaches two, both the stocks and the production targets reach infinity. Therefore, if we want to choose an optimum value of α so that the changes in both the stocks and production targets are minimum, α should be less than one. For example, it would be advantageous to select α 0.3, but we cannot say whether this is the optimum value for the given condition.

Depending on the method of selecting standard planned production over a long period, there may be a case of zero stocks. Efforts would have to be made to replenish the stocks through imports. If this is impossible, we must limit consumption.

If we consider the yearly stocks and make correct production plans, there can be a regular supply of rice. However, both excessive vigilance and neglect are harmful. So far we have considered the mathematical equations. Now using them, let us formulate the mathematical model.

Table 18. The characteristics of the coefficient used in the model for rice supply

	Latitude of changes in stock $\frac{1}{\sqrt{\alpha(2-\alpha)}}$	Latitude of changes in planned production $\sqrt{\frac{\alpha}{2-\alpha}}$
0	∞	0.00
0.1	2.30	0.23
0.2	1.67	0.33
0.4	1.25	0.50
0.6	1.09	0.66
0.8	1.02	0.82
1.0	1.00	1.00
1.2	1.02	1.22
1.4	1.09	1.53
1.6	1.25	2.00
1.8	1.67	3.00
2.0	∞	∞

Let us take the standard consumption as 100. This value will change slightly with changes in temperature; if the temperature is 1°C lower then consumption increases by about 4%. When the temperature is 1°C lower, production also decreases by 30%. Yearly changes in temperature in terms of the standard difference are about 0.3°. Accordingly, consumption will change by about 1% and production by about 9%. To counter these changes we assume that standard stocks increase by 30% of standard consumption.

Let us assume that the difference in temperature is a purely arbitrary phenomenon. Using a random number, we will construct a model of the periodic changes in temperature by examining temperatures over a long period of time. We must assume in this model that the standard stocks initially exist and if we take the value of parameter α, which determines production targets, as 0.0, 0.2 and 0.8, then the changes in yearly stocks, using the first equation, will be as shown in Fig. 17. The changes are gradual when α is zero but the latitude of change is very wide and this is advantageous when we want to consider a period of about 40 years. Theoretically, if sufficient time elapses it may reach infinity. Then, too, the initial stocks of the year may decrease the consumption to a great extent. Therefore, this method cannot be adopted in actual practice.

By comparison, if we take α as 0.2, the pattern changes completely and there is a variation of about 130%. The phenomenon of stocks affecting consumption occurs only in an emergency. This appears to be a change over seven to eight or even 20 years.

If we take α as 0.8, the latitude of change is reduced slightly and resembles short term change. This supports the results obtained from the mathematical equations. This is a simple model after all and the actual changes may not follow the plan. There are many other factors, including increasing population and progress in cultivation techniques, which influence change. However, we can claim the following: there are some changes in the supply of rice every year and the effect on stocks is significant over a long period of time. If we consider the present stocks and adjust the production for the next year, the changes will be small, but if adjustments are made over a long period the level of planned production will change greatly. The best policy for a regular supply of rice is, then, to consider all these factors together and act accordingly.

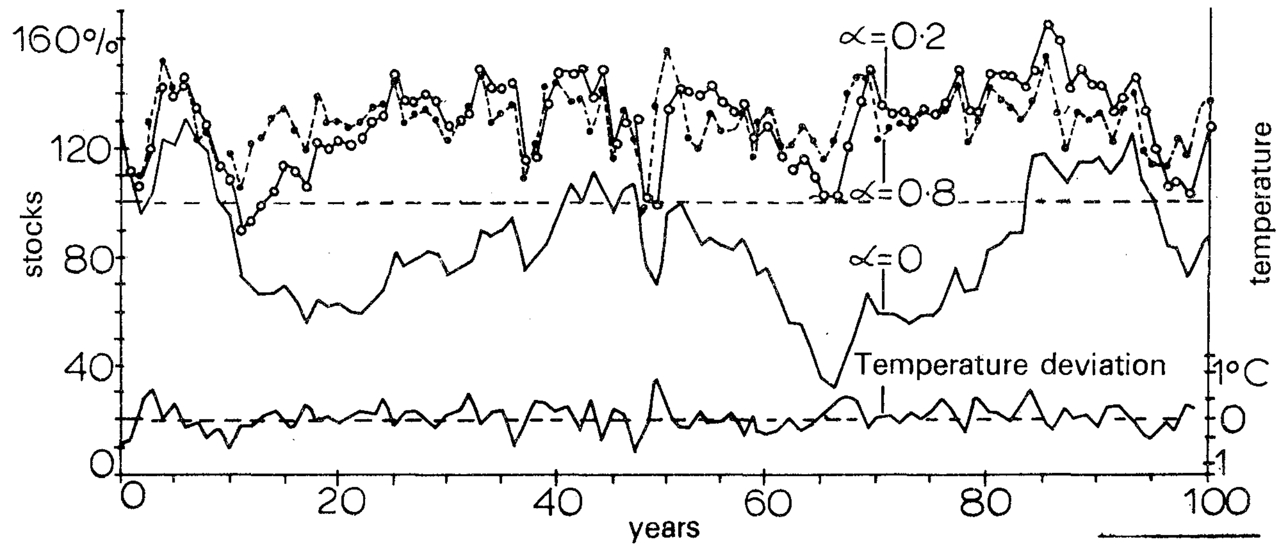
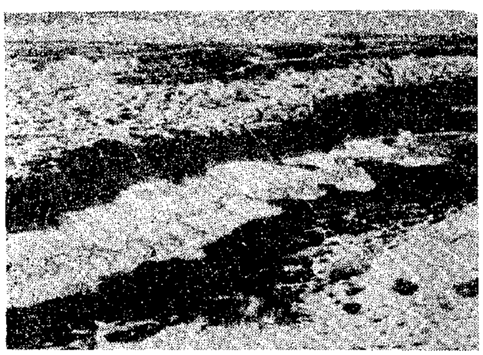


Fig. 17. Fluctuations in the yearly stocks of rice.

In this model we have considered only rice, but the same model can be used for other products. When we study the changes in the stocks of Fig. 17, for $\alpha = 0.2$ or $\alpha = 0.8$, a periodicity of seven years can be observed. The stocks are closely related to economic prosperity, which is also said to have a period of seven years. Interestingly, this can also be determined from our model.

Chapter Ten

Changing Climate



Alaskan iceberg viewed from a height of 10,000 m.

During the 'Mizunoe' year of the Tenmei* period, it rained from the beginning of March till the middle of July. Cold weather continued from May until August. As a result, crops failed miserably. The wheat fields were flooded on the 26th of June. Such floods appeared continuously for two years, Ushi and Tora, and the harvest also was very poor.

Tenmei Kyukouroku

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*There is a cycle of 60 years in the old Japanese calender. This is subdivided into two classes, a 12-year cycle and a 10-year cycle. Each of the 12 years is named after an animal: the mouse, cow, tiger, hare, dragon, snake, horse, sheep, monkey, chicken, dog and wild boar. The years in the second cycle have similar names and each year is identified by both names. The same combination will not be repeated for 60 years. Thus a man would normally come across each combination only once in his lifetime and there was no need to identify any particular year further.

CAUSES OF RECENT CLIMATIC CHANGES

At the beginning of the Showa period (1927), many meteorologists held that climate does not change. In the ancient geological eras, however, such dramatic climatic events as the Ice Age certainly caused changes in the earth's weather. We also know that the same weather is not repeated each year and that there are warm years, cold years and many variations. However, there are certain standard conditions for weather over the years and it was thought that weather fluctuates around these norms.

After World War II, as if in the regular course of nature, warm winters continued and there were abnormally strong typhoons, including the Makurazaki typhoon, Typhoon Catherine, Ise Bay typhoon and others. The summers were often hot and good harvests followed. These facts cannot be explained with the assumption that climate does not change and in recent decades meteorologists have abandoned the old theory.

Fluctuation in climate is not restricted to Japan, but is a world-wide phenomenon, more severe at the poles. Scherhaag of Germany suggested at the beginning of the Showa period that since the beginning of the twentieth century, the temperature has been rising rapidly and that the ice on the polar caps is melting. If we compare the temperature in 1940 with that in 1900 in the Arctic Ocean at Spitsbergen (Svalbard) we find an increase of about 3°C and during the winter of 5° to 6°C.

This tendency in the postwar period for temperatures to increase is unusual. Some scientists have suggested that this is a result of expanding human activity. Depending on the consumption of fossil fuel that man uses for production, the carbon dioxide in the atmosphere increases and its warming properties result in a rise in temperature.

The temperature in big cities is certainly higher than that in the suburbs. Some call this phenomenon a 'heat island.' It is obviously the result of human activity, but whether the increase in temperature on a world scale is due solely to human activity is debatable. In the past there were high and low temperature periods which cannot be explained on the basis of changes in human activity. Again, if the recent increase in temperature is to be attributed to human activity alone, the temperature should increase continuously. But the period of high temperature seems to be almost over in Europe and elsewhere, the temperature has been falling for the last 20 years. A good example is the abnormal weather of the winter of 1963 (Fig. 18). If such a low pressure phenomenon is assumed to be accidental, then statistically speaking it should not be repeated for a few thousand years or even a few hundred thousand years. This phenomenon occurred not only in Japan, but in Europe and North America. The Seine River in Paris, for instance, was frozen. This kind of cold weather has not been recorded for the last 150-160 years; compared with the average, temperatures were 9°C below normal.

Figure 19, showing temperature deviation in the northern hemisphere in January 1963, reveals that such abnormally low temperatures also occurred in Europe, Central America and the Far East. However, the region between Siberia and Alaska, from Iceland to the northeast region of North America, experienced abnormally high temperatures during the same time. This suggests that the cold atmosphere of the north and the warm atmosphere of the south interchanged.

These extraordinary phenomena did not stop there. In western Japan rain began in May, one month earlier than usual and instead of the usual pleasant weather of early summer, cloudy skies continued. This resulted in serious damage to the barley crops and the harvest was only half the normal level. The cold winters of 1963 and 1964 also affected the textile industries and production suffered. In April 1964, the temperature rose to unusually high levels and was 5°C above average in western Japan. This broke all records kept since the beginning of meteorological observations.

This is more than five times the standard deviation normally determining the level of change from year to year. Statistically speaking, this change did not start in January 1963, but in September 1962. During that season of typhoons, none appeared; during the rainy season of the Kanto region, there was no rain.

Thus, over a long period of time, strange atmospheric phenomena may occur; these abnormal weather conditions have a tendency to occur in close succession.

Extraordinary weather conditions occur even today on a global scale. In the summer of 1972, the temperature in the USSR and India rose to unusual levels, in Canada it was a cold summer and Australia and China were abnormally dry. As a result, harvests everywhere were seriously damaged and China and the Soviet Union had to import wheat in large quantities from the USA. This extraordinary climate also affected Japan: prices of soybeans rose steeply, rice was sold out and some planners even considered reversing the policy of limited rice production.

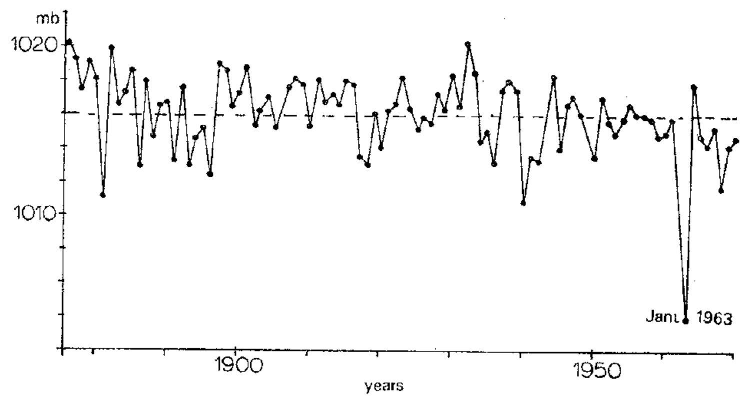


Fig. 18. Average atmospheric pressure in January in Tokyo.

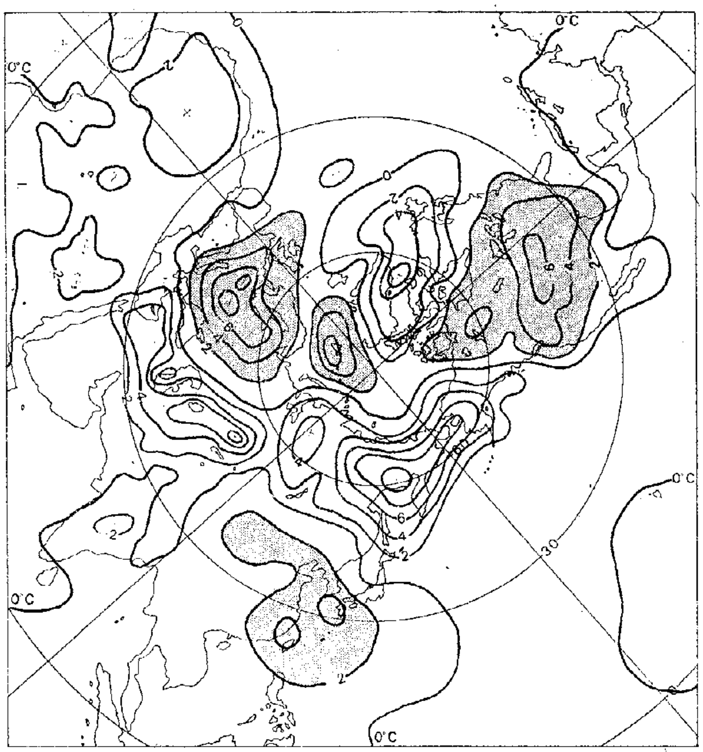


Fig. 19. Decrease in atmospheric temperature in the northern hemisphere in January 1963.

If we observe climatic changes longitudinally, they appear to be related to food production which seriously affects society. Near the polar region, climatic changes take the form of change in the amount of ice in the sea which seriously affects marine transport.

Meteorologists and weather experts the world over are interested in these phenomena. An international symposium on climatic changes was held in 1962 in Rome. Ram, of the United Kingdom, has published several books concerning climatic change.

What is the relationship between the climate and abnormal weather? The standared climate is determined at an international level by taking the average of 30 years. The climate of each year differs from the standard climate because of variations in prevailing conditions. For example, in Japan the average monthly temperature often varies in different regions by about 1°C from the average for the year. However, it does not usually vary by 3°C. Therefore, the 1°C change is not unusual, but a 3°C change is extraordinary. Thus, to differentiate between normal and abnormal conditions, the standard climate (which is the average over 30 years) serves as a base line, that is, if a phenomenon occurs which had not occurred in these 30 years, it is abnormal. Now, if we assume that the climate does not change then abnormal situations should not continue for several years in succession. If we accept the fact that there are long term changes in climate, then extraordinary climatic situations can arise and this abnormality in itself confirms the assumption that climate is not very steady.

LATITUDINAL CHANGES IN THE CLIMATE

We shall now consider the climate in historical perspective since forecasting changes in climate in the future requires an understanding of the situation in the past.

Meteorological observations using scientific instruments have been conducted in Japan for the last 80 to 100 years. In Europe they have been underway for 200 years. By analyzing the results, we can calculate the changing climatic patterns in mathematical terms. The records of other phenomena, which are related to climate, also have indirect value. For example, harvests, the rings of a tree, records of snowfall or glaciers or diary entries describing the weather can add valuable information on changes in climate. The work of Arakawa Hidetoshi is interesting in this respect. He studied the days of "Hanami" (the season for watching Sakura flowers) in Kyoto from the eleventh to the fourteenth centuries. Since in those days the season started four days later than it does now, he concluded that spring temperatures then were lower than they are now. Similarly, if we study the records of the freezing of Suwa Lake, we find that the winters were mild between 1505 and 1515 since the lake did not freeze. A similar phenomenon is also reported in the latter half of the 1860s.

Similar research is underway all over the world with particular reference to the climate during the Christian era: an appreciable change in climate is known to have taken place over a long period of time. The pattern of change is very complex and changes vary in different regions. However, it appears that the climate between 4000 B.C. and 2000 B.C. was mild and favorable.

After 1300 B.C. there were frequent floods and heavy rainfall in Europe and elsewhere and temperatures dropped. The climate was particularly unfavorable in 500 B.C., but later returned to normal and was not very different from the present. Between 1400 and 1600 A.D. the temperature was very inconsistent and the number of glaciers increased. The period from 1600 to 1850 A.D. was noted for small glaciers and during 1650, 1750 and 1850 A.D. the glaciers were as extensive as mountains. During 1783, which falls within the small glacier period, Japan suffered a severe drought. In the years just before and after, the summers were very cool and there were many starvation deaths. Thereafter the climate was generally good with only slight variations. But since 1900 the temperature has been rising continuously. This fact has been repeatedly confirmed.

Using the data from meteorological instruments and other records we will examine the changes in climate after 1700 A.D. Fig. 20 shows the 30-year average values of the temperature, rainfall, number of solar black spots, frequency of poor harvests in Japan, number of typhoons and other factors. The black and white circles represent the average values of 10 and 30 years, respectively. The general tendencies in climatic changes cannot be observed from the average values for 10 years or 30 years even though the changes are considerable; since the 30 years average is accepted on a global scale, these values have been plotted.

According to this figure, the temperature has been rapidly increasing in the United Kingdom and Stockholm since 1900. This change parallels the number of solar black spots. In contrast, changes in Madras, in the tropical region, are small.

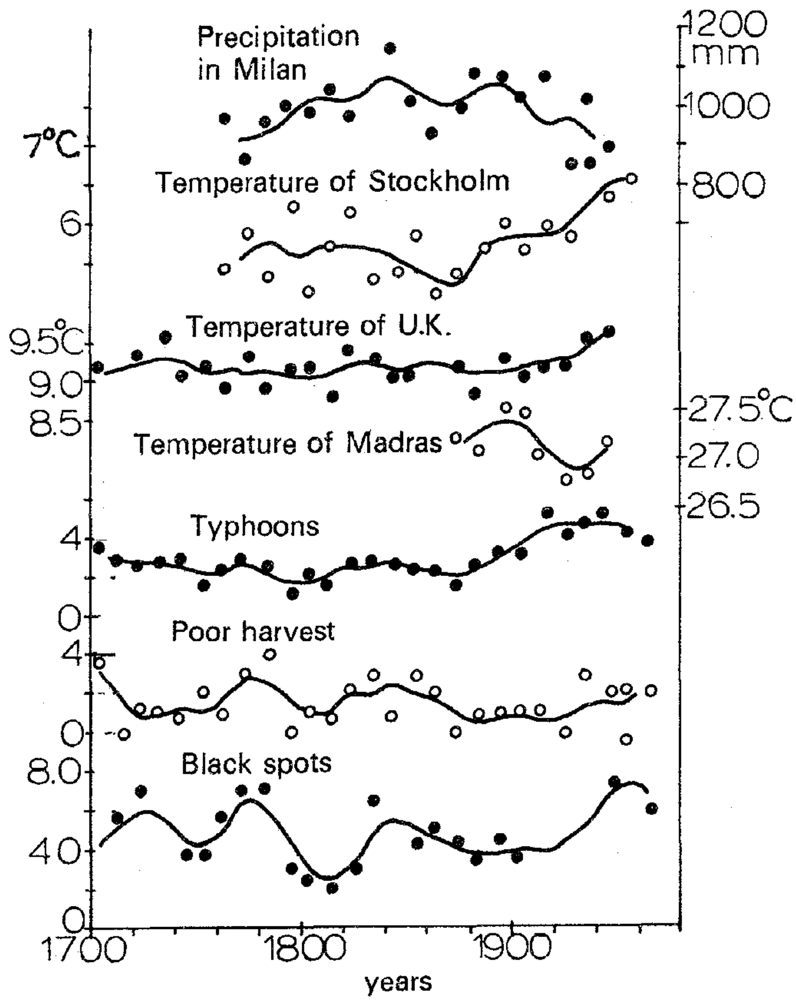


Fig. 20. World-wide atmospheric changes.

This is one of the characteristics of change in world temperature: as we get closer to the poles the climatic changes are greater whereas at lower latitudes they are smaller and in the opposite direction. The temperature data for the United Kingdom are based on the survey by Manley while the earlier estimates are based on historical documents.

The long term changes in the amount of precipitation in Milan, Italy, are not of the same order as long term changes of temperature. On a short term basis, however, the changes are many and complicated.

There are no reliable data for Japan prior to 1880, but from the frequency of poor harvests over ten-year periods and from the damage due to typhoons, Fig. 20 indicates that the changes parallel the changes in the number of solar black spots just as in the case of the United Kingdom. The strength of typhoons has apparently been increasing since 1900, but this may only reflect the imperfect data of earlier periods.

The temperatures in the United Kingdom and Stockholm and the long term changes in the frequency of poor harvests vary in similar ways. This contradicts the axiom that high temperatures bring good harvests. This contradiction can be explained by the "blocking" phenomenon: when the winds in the atmosphere above the medium latitudes become very irregular, the tides become turbulent and the shifting of low pressure belts is completely blocked. In other words, the warmer air of the lower latitudes and the cooler air of the higher latitudes interchange and abnormal weather conditions prevail. When blocking occurs, the heat of the lower latitudes is carried to the higher latitudes, raising the temperature. A higher temperature at higher latitudes indicates that an exchange of north and south air is taking place smoothly and a blocking phenomenon exists. When blocking occurs, depending on the positions, the cool air of the higher latitudes moves south and as it enters the belt the temperature in the south falls below average. When the warmer air of the lower latitudes moves, the temperature suddenly rises in the north. These are abnormal weather conditions.

In examining world-wide temperatures we do not find either extremely high or extremely low temperatures throughout the world. Instead, if there is a region of extremely high temperatures there must be a region with very low temperatures. When the winter of 1963 was abnormally cold in Japan, the winter in Hokkaido was warm. This is another example of the exchange of warm air and cool air causing extreme heat or extreme cold.

Weather changes and extraordinary climates differ in intensity and modes depending on the time and space scale used for reference. Fig. 21 shows the difference in long term weather changes using an average of 35 years from 1916 to 1950 and from 1881 to 1915 in terms of temperatures (a) and rainfall (b). Although the findings are not current, we see that temperatures are increasing with the pole at the center. The increase is great at higher latitudes, whereas at lower latitudes the temperature is decreasing slightly. Data on rainfall show a similar pattern: at higher latitudes the amount of precipitation is increasing but in subtropical regions it is decreasing slightly. This indicates that between 1916 and 1950 the interchange between north and south was smooth with the heat and water vapor from the lower latitudes being carried toward the higher latitudes.

So far the values are near the standard 30 years average, but if we consider a shorter period the results are different. For example, during the abnormal weathers of January 1963, if we study the deviation in monthly average temperatures of the northern hemisphere during the abnormal weather of January 1963 we find that in the same semi-cold zone the regions of low temperatures and high temperatures are alternately dispersed as can be seen in Fig. 19. This is completely different from the 30-year average and the blocking phenomenon can be observed directly.

The more data considered, the more difficult it is to explain weather changes. The climate of a region is generally determined by long term average values, but if the period under consideration is shortened the values change and the controlling factors also change.

FACTORS AFFECTING CLIMATE

Various explanations for climatic changes have been offered throughout history, but the main ones appear to be the following:

1. Continental shifts
2. Changes in the rotation and revolution of the earth
3. Changes in solar activity
4. Changes in ocean currents
5. Polar ice and snow conditions
6. Changes in the structure of the atmosphere.

For geological eras or very long periods, the first and

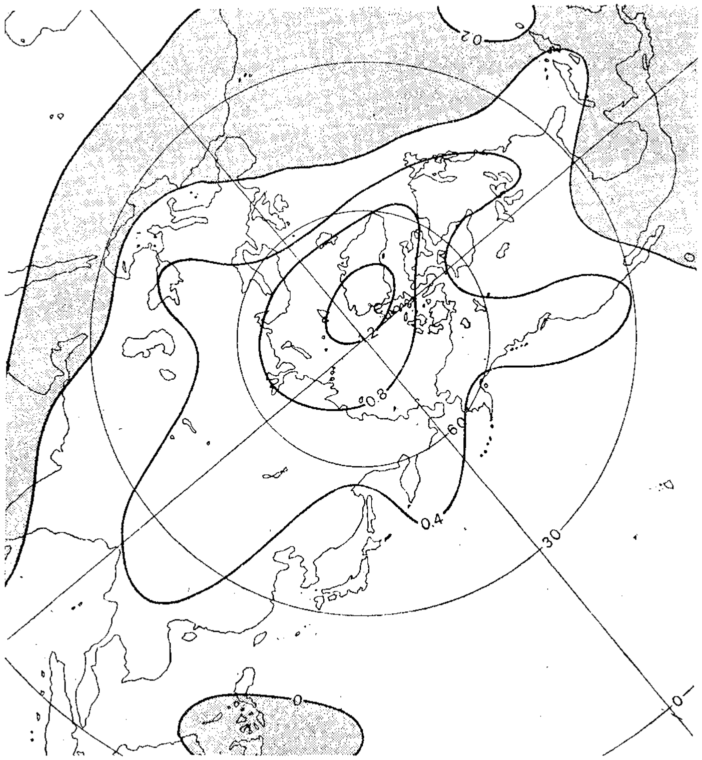


Fig. 21a. Long term changes in temperature (1916-1950) (1881-1915).

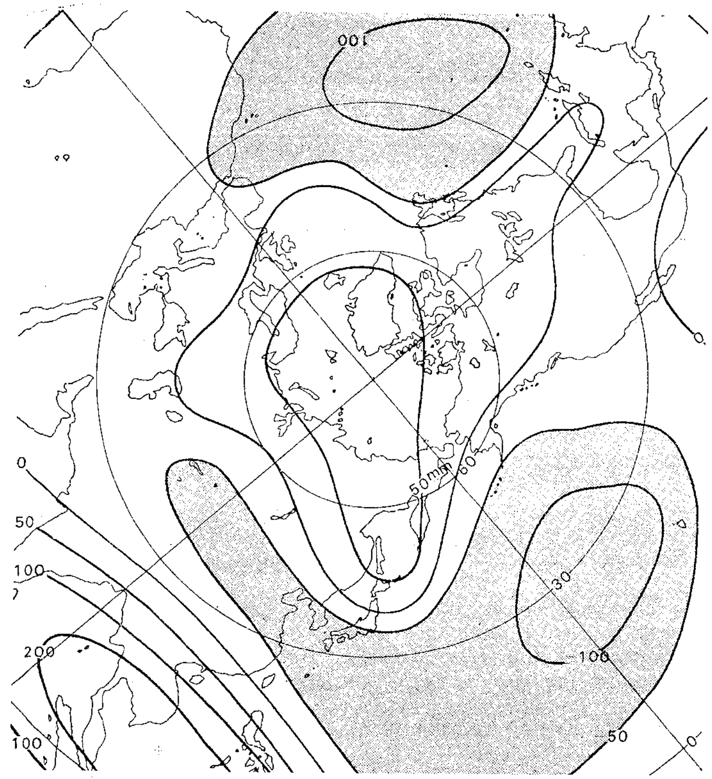


Fig. 21b. Long term changes in rainfall (1916-1950) (1881-1915).

the second are the major factors, but for a few years or few hundred years these factors are irrelevant. Unless we clearly specify the time scale we can make no valid conclusions.

Let us look at the present. Why have changes in climate occurred during the last few decades? One factor is the ocean. Sea water has great heat conducting properties. Once the ocean warms up it does not cool quickly and this may affect the climate. The temperature of the sea water in 1963 was abnormal. Whenever the temperature of the Kurile current is very low there are poor harvests in northern Japan. This does not prove that the sea is the main factor since the same factors which control the climate may also control the conditions of the ocean.

Another important factor related to the effect of the sea is the effect of polar ice on the climate. Since snow is white, it reflects the sunlight. When the amount of ice increases, less heat is absorbed by the earth so the temperature drops. Climatic changes are very apparent in the polar region and the long term changes in the amount of polar ice or glaciers parallel changes in temperature. But we cannot say categorically whether the temperature drops as a result of the increase in ice or the ice increases because of lower temperatures. Nonetheless, there is a correlation between the two.

Change in the solar activity is another important factor. Almost all the energy for meteorological phenomenon comes from the sun. Therefore, if there are changes in solar activity, they will cause changes in weather. The periodic changes in solar black spots correspond to weather changes.

Many scholars disagree with this theory. Stated simply, when solar activity becomes vigorous, the energy radiated by the sun increases, thereby increasing the atmospheric temperature. However, data do not tally with this. Certainly, the ultraviolet rays and the photon particles radiated by the sun increase greatly and the aurora becomes very bright. But, when we look at the total amount of heat radiated by the sun, we find that monthly change is very small or nil. Furthermore, solar black spots have a cycle of 11 years, but weather changes do not correspond to this. Hence, if any relation at all exists between weather changes and solar activity, there must be some other physical process connecting these phenomena.

An old study by Clayton on the relationship between solar activity and the weather interests scholars even today. Of particular interest is the effect of the flow of photon particles radiated from the surface of the sun; this is also known as solar wind. The surface of the sun is called the solar flare. When explosions cause the solar flare to become bright, the flow of photon particles becomes very strong. They enter the earth's atmosphere after two or three days when the aurora can be seen in the solar region and cause change in the earth's magnetic field. Sometimes the "Delinger phenomenon" occurs and electrical communications are disrupted.

Mathematical research has not been able to determine whether this affects the lower layers of the atmosphere, but it is believed to have some effect on weather conditions. Many research papers have indicated that there is a statistical correlation between the flow of photon particles and weather conditions. It has been found that after a strong flow of photon particles reaches the earth, air pressure is easily generated and rainfall is more likely. When solar black spots increase, the solar flare also increases and the interchange of air between the tropical region and the polar region becomes vigorous, thus paving the way for a blocking phenomenon. Changes in solar activity then are one of the major factors affecting weather conditions.

One problem in studying the relation between solar activity and weather conditions is the mediating effect of the clouds. The temperature of the earth is determined by the amount of heat coming from solar radiations and the amount of heat radiated by the earth. However, the amount of solar heat falling on the earth's surface varies depending on cloud cover and the amount of heat radiated by the earth is affected by clouds as well as the humidity of the atmosphere. The reflection and absorption of solar radiation depend on the condition of the earth's surface. In addition, snow and vegetation play a part. Air and ocean currents, phenomenon through which heat transfer occurs, are also important. Sea water evaporates, turns into clouds and rains. Here too heat exchange is important. It may have positive or negative value depending on the processes of cooling and coagulation of ice particles in the clouds.

The factors controlling the weather are many and interrelated. There are some factors which have not yet been identified and more mathematical research is required to understand the reasons for weather changes. A model should be made which would reflect the given conditions and then the effects of different factors could be studied. Research on atmospheric cycles using electronic computers is underway in the USA and Japanese scholars, Manabe Yoshira and Arakawa Akio, are also engaged in research.

CARBON DIOXIDE IN THE AIR AND CLIMATIC CHANGES

So far changes in climate have been explained largely in terms of expanding human activities. For example, smoke and fumes from burning chemical fuels pollute the air and prevent sunlight from reaching the earth's surface, resulting in a drop in temperature. Another interpretation, however, is that when a chemical fuel is burned, carbon dioxide is generated and accumulates in the atmosphere; because of its warming properties, the temperature rises. Both explanations are plausible and neither should be disregarded.

Industrialization has expanded rapidly in recent years throughout the whole world. Then, too, the carbon dioxide content of the atmosphere is vital in the survival of life. Let us then consider the movements of carbon dioxide in nature to better understand the effects of human activities.

We shall examine first the composition of the earth's atmosphere. Of approximately 5100 trillion tons, 2.3 trillion tons is carbon dioxide. In 1970, about 12 billion tons of carbon dioxide was released into the atmosphere due to burning fuels. If fuel consumption continues at this rate, within 200 years, the resultant carbon dioxide in the atmosphere will equal the present amount. Calender analyzed the percentage of carbon dioxide in the atmosphere and reports that the amount of carbon dioxide in the atmosphere today has increased by about 10%. This is the same as the amount released due to fuel consumption by man; therefore, it can be attributed only to this fact.

Although there is no error in the calculation itself, whether or not the carbon dioxide in the atmosphere actually increased by 10% cannot be easily verified. Even if we assume that it did not increase, we cannot be certain that it was due only to human activities. The respiration of other living things and the decomposition of matter also contribute to carbon dioxide in the atmosphere. The amount due to decomposition is about 200 billion tons which is 17 times the amount due to fuel. If we assume that this carbon dioxide remains in the atmosphere, the amount will double in only 11 years. However, this does not actually happen as plants break down the carbon dioxide and release oxygen through photosynthesis. Animals inhale oxygen and exhale carbon dioxide while breathing, but in photosynthesis oxygen is returned to the atmosphere in its original form. The amount of carbon dioxide in the atmosphere is then determined by the balance between these two processes. There is not enough carbon dioxide in the atmosphere for the plants so that if the carbon dioxide increases then photosynthesis will be more vigorous, consuming more carbon dioxide. Carbon dioxide will then decrease again.

Sixty times the quantity of carbon dioxide in the atmosphere is dissolved in sea water. The effect of sea water is therefore significant. Even though man releases carbon dioxide through fuel consumption we cannot determine whether carbon dioxide has actually increased or not throughout the total atmosphere and if it has increased, to what extent.

In big cities the amount of carbon dioxide is increasing. Large quantities of carbon dioxide are released and the trees and plants which decompose it are relatively few.

Clearly the activities of living beings greatly affect the composition of the atmosphere. The amount of carbon dioxide in the atmosphere is constantly changing. It is estimated that it undergoes one complete cycle within 350 years. The same is true for oxygen. As the volume of oxygen is much greater than that of carbon dioxide, changes in its quantity are slow. It is estimated that one cycle takes about 2000 years. This period is short, however, compared with the earth's life.

The present condition of the atmosphere of the earth is due to the movements of living beings and these have recently expanded greatly. At the origin of the earth there was neither atmosphere nor oceans. Gradually gases developed and the atmosphere and oceans formed. During this time the atmosphere was composed mainly of methane, water, ammonia and other gases. These elements began to absorb the ultraviolet rays from the sun (which are otherwise harmful to life) and the first life appeared on the earth's surface. This is estimated to have occurred about 2.5 million years ago. Thereafter the composition of the atmosphere changed rapidly and ultimately reached its present state.

This estimate is supported by a variety of evidence. No other planet has a similar atmosphere. The atmosphere around the planets on the outer side of the earth's orbit contains mainly methane and ammonia and those on the inner side are said to have a lot of carbon dioxide.

We have discussed carbon dioxide in great detail, but it is important to note that carbon dioxide is not presently harmful to life. Carbon dioxide passes through sunlight and absorbs the heat. Therefore, if the volume of carbon dioxide increases in the atmosphere, its warming effects increase and the temperature of the atmosphere increases. Some scholars consider this important. Plass, for example, says that if the amount of carbon dioxide in the atmosphere doubles then the temperature increases by 3.8°C.

Other matter, including water vapor, have similar warming properties. Clouds also affect the atmosphere to some extent, complicating calculations still further.

Manabe Yoshiro has prepared a model similar to actual conditions of the atmosphere and has conducted some mathematical experiments. According to him, the temperature has risen by 2.8°C.

On a global level, the amount of carbon dioxide has not increased by even 10% over the past and the temperature increase is only 0.3°C. This then cannot fully explain the present increase in temperature.

CLIMATE OF JAPAN IN THE 1970s

We shall now turn to changes in Japan's climate. Using data from the past, we shall try to forecast the climate for the future.

Figure 22 shows the ten-year average values of different elements of the climate of Japan (see also Table 19). The temperature and rainfall of Japan have been determined from the average values of six places: 1 - Nagasaki, 2 - Kyoto, 3 - Tokyo, 4 - Niigata, 5 - Miyako and 6 - Hakodate.

Table 19 indicates that the temperature reached its lowest point in 1905 and then started rising. In 1960 it rose by more than 1°C. The minimum air pressure in Japan occurs every year in the typhoon season; the lower the pressure, the stronger the typhoon. The pressure was highest in 1905 and tends to decrease as we approach the present. That is, typhoons are becoming stronger every year. The long term changes in these two factors correspond to long term changes in solar black spots.

The data for rainfall differ from that for temperature. Rainfall was low in 1890 and 1935, suggesting a periodicity of 30 to 40 years. The frequency of typhoons was also less in 1890 and 1935, corresponding to the changes in rainfall. The difference in air pressure during December, January and February at Nagasaki and Nemuro is indicative of changes in seasonal winds; higher pressure means stronger seasonal winds and lower temperatures. This change is the exact opposite of changes in rainfall.

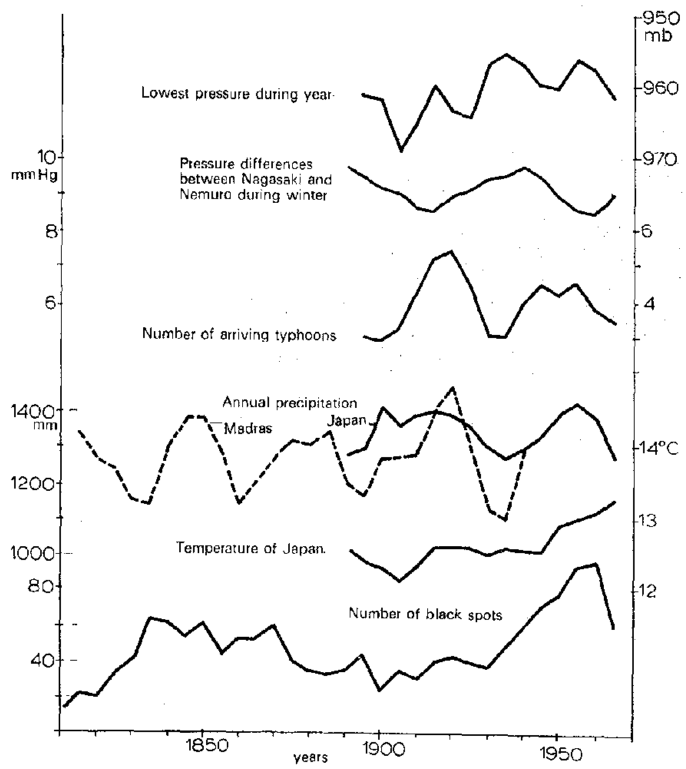


Fig. 22. Atmospheric changes in Japan.

The 35-year periodicity of rainfall was discovered by Bruckner and therefore is known as the Bruckner cycle. The measurement of rainfall in Japan has been conducted for less than 100 years. However, it has been done in Madras since 1810. When we compare change in rainfall in Madras with that in Japan we find it similar and there are at least four 35-year periods.

Some people question the Bruckner cycle, but its validity is almost certain. The reason for the periodicity is not clearly understood, but it is thought to be related to air pressures in the polar region. The regions of heavy ice or snow tally with this conclusion.

The main characteristics of Japan's climate in the 20-year period after World War II include higher temperatures, heavy rainfall, the possibility of strong typhoons, comparatively weak seasonal winds during the winter and, as a result, less snowfall.

Table 19. Atmospheric changes in Japan

Year	No. of black spots	Average temperature in Japan, °C	Average rainfall in Japan, mm	No. of typhoons	Pressure difference during winter (mm of mercury) Nagasaki-Nemuro	Minimum pressure millibar
1886-1895	39	12.6	1494	-	8.9	-
1891-1900	45	12.4	1539	3.1	8.5	961.0
1896-1905	25	12.3	1628	3.0	8.2	961.0
1901-1910	36	12.1	1588	3.4	7.9	969.2
1906-1915	30	12.3	1604	4.6	7.6	965.1
1911-1920	41	12.6	1615	5.2	7.5	960.1
1916-1925	45	12.6	1609	5.4	7.9	962.9
1921-1930	42	12.6	1579	4.3	8.2	964.1
1926-1935	40	12.5	1508	3.1	8.4	957.4
1931-1940	54	12.6	1488	3.1	8.5	956.5
1936-1945	60	12.6	1500	4.1	8.9	957.1
1941-1950	74	12.6	1553	4.6	8.4	960.4
1946-1955	76	12.9	1607	4.2	7.7	960.4
1951-1960	94	13.0	1634	4.3	7.5	956.4
1956-1965	93	13.1	1592	3.8	7.4	957.4
1961-1970	60	13.3	1494	3.5	8.1	962.1

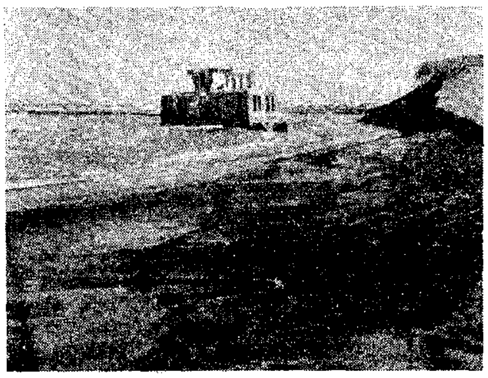
What will the climate be in the future? Since the factors affecting the climate are not very clear, it is difficult to predict the future. However, the effort must be made if we intend to suggest countermeasures and certainly while considering the future of Japan, we must include climatic changes. For any predictions to be valid, of course, they must be based on experience.

A comparison of the long term temperature changes of Japan and Europe reveals similarities. The changes are also similar to the changes in the number of solar black spots. An analysis of the number of solar black spots indicates that cycles vary, but over a long period they seem to have two cycles, 55 years and 80 years. The number of black spots then decreases and the temperature falls accordingly, particularly in high latitudes. The year 2000 A.D. may then be the coldest period. This does not mean that the number of poor harvest years is going to increase. Assuming that the Bruckner cycle exists, the rainfall will be less and the typhoons will be fewer during the 1970s and the seasonal winds of the winter will be very strong. As a result, the snowfall will increase. In 2000 A.D. once again the rainfall and the number of typhoons will increase and the winter seasonal winds will be weak. During the 1970s, the winter seasonal winds will become weak, there will be heavy snowfall, the number of typhoons during the summer will be fewer and rainfall will be less. The temperature will fall substantially.

In the 1980s the rainfall will again increase and the climate will be similar to that recorded in the beginning of the Meiji period. This is a very broad conclusion, however, and it may be hazardous to plan countermeasures on the basis of these data. International interdependence is expanding so greatly today that the effect of our climate is not limited only to Japanese society but must be considered on a world scale. Our studies do confirm that the climate undergoes some change and we can anticipate some of the changes mentioned occurring in the future. Researchers must now study the climates of all the regions of the world.

Chapter Eleven

The Threat of Earthquakes



Maritime work at the sea coast (Niigata Prefecture).

On October 14, 685 A.D., in the twelfth year of the reign of Emperor Temmu, a severe earthquake rocked all of Japan. In the Tosa region (Shikoku), about 50 rice fields were submerged in the sea and the hot springs of the Iyp region (Shikoku) sprang up as fountains.

NIHONSHOKI
(Ancient Chronicles of Japan)

DAMAGE DUE TO EARTHQUAKES

Earthquakes occur frequently in Japan. Since ancient times there have been many severe quakes and much serious damage. This factor must not be overlooked while considering Japan's future.

Nearly 50 years ago on September 1, 1923, at 1:58:44 p.m. a severe earthquake shook the Kanto region. I was a child in primary school and my family had only recently moved from Fukagawa to a place near the present Iidabashi station of the Japan National Railroad. That morning I had accompanied my mother to school to register. Upon returning home, I was resting when suddenly the china umbrella stand kept near the entrance jumped about 30 cm and broke into pieces. That was the beginning of the Kanto earthquake. The vibrations were then so severe that houses collapsed and roof tiles fell. The boundary wall beyond the garden shook and we could see 3 cm wide cracks appear and disappear. That was terrifying. When the vibrations slackened later, I went out. Many people were taking refuge on the tram tracks; they would start chanting prayers whenever vibrations began again.

The center of that earthquake was in Sagami Bay and its strength was 7.9 on the Richter scale. Its strength in the southern part of the Kanto region was a little over seven on the Richter scale and it caused turbulent waves 6-8 m high near the sea shore.

Tokyo and Yokohama were ravaged and fires broke out which spread widely. This calamity claimed 144,000 persons dead and missing. In the severe damage more than 128,000 houses collapsed and over 447,000 were consumed by fire. Many people took shelter in the restrooms of big offices.

Unfortunately, a holocaust then occurred, claiming 35,000-36,000 lives. This colossal disaster was not simply due to the hot waves of air rising from the fires. The weather diagram of that time indicates that there was a typhoon in the Noto Peninsula and hot and humid air currents entered the Kanto region. This may have been the real cause of the calamity for had there been no typhoon, so great a disaster might not have occurred.

The damage at that time was some six billion yen. Converted into 1973 values, it is about 2,000 billion yen. This was a severe blow to Japan's economy and some have suggested it was one of the causes of the recession in the early Showa period.

A Seismological Research Institute was later established at Tokyo University to attempt to predict earthquakes. Serious research was conducted at the university in such areas as seismology, earthquakes, engineering and related fields and data accumulated rapidly. However, such a calamity occurs only once every few decades and man is a forgetful animal. In the early Showa period, when Japan entered World War II, precautionary measures against earthquakes slackened somewhat. After the war, as the restoration of Japan progressed and the world returned to normal, the scientific community again began to focus on this problem.

In 1961, the Committee for the Prevention of Fire Disaster of the Tokyo Fire Defence Board estimated the amount of damage if an earthquake similar to the Kanto earthquake in strength were to occur in Tokyo. They reported that the damage would not be reduced at all in spite of the remarkable progress of civilization and would, in fact, be about the same as in 1923. Under the circumstances, even more disastrous calamities are possible. As a direct result of an earthquake, some 17,000 houses could collapse. While this figure may not seem so high, if fire broke out at hundreds of places the losses due to fire accidents would account for one-third of total loss. Downtown areas are particularly vulnerable to the danger of fire; the Yamanote area is less so. The casualties could be in the same range as before and might reach 100,000.

Today, 15 years after this prediction, the situation has not changed. Indeed, with present economic growth, damage could be even greater. In the construction of skyscrapers today, architects incorporate anti-earthquake measures so the buildings will probably not be destroyed. However, in an earthquake in Los Angeles on February 9, 1975 at 11 p.m. (JST) the damage was very heavy. The strength was only 6.5 on the Richter scale, but the casualties were about 65 and the earthquake was considered B class. The freeways were heavily damaged and traffic was completely dislocated.

This example suggests that, in future earthquakes, express highways will be destroyed and cars will be immobilized. Electricity and water will be cut off and railways and communication will be paralyzed. In short, city life will come to a standstill. Automobiles stranded on the highways will add their gas to any fire that starts, adding enormously to the damage. The casualties could then exceed any previous record.

The Kanto earthquake was 7.8 on the Richter scale. On the Gutenberg scale this is near the maximum but is not the highest value possible. Therefore we should be prepared for an even stronger earthquake.

The Southeast Sea earthquake on December 7, 1944 registered 8.3 on the Richter scale. It caused tidal waves that razed about 29,000 houses and the casualties amounted to thousands. Damage did not exceed that of the Kanto earthquake, but only because it did not occur in the Tokyo region. Had it occurred there, the damage would have been much more severe.

PREDICTING EARTHQUAKES FROM CHANGES IN THE EARTH'S CRUST

We cannot prevent earthquakes. We can only reduce the damage or distribute it over a wider area. Earthquakes are a natural phenomenon and damage is unavoidable. But even a severe earthquake will not cause much damage in a wilderness. Therefore, the concentration of national wealth in Tokyo makes Japan very vulnerable. Since the probability of an earthquake has not decreased, we should decentralize the population, construction and so on even on a long term basis. Then the earthquake damage would not threaten to wipe out centers of industry, communications and government simultaneously. The concentration of population in big cities is itself a problem today and we should start considering a more even distribution of people, construction and industry over a larger area. However, easy it is to suggest, this remains very difficult to implement.

What then should be our line of action? Prediction of an earthquake is an important first step for if we can predict earthquakes well in advance, countermeasures can be planned. To this end seismologists like Wadachi, Tsuboi Tadaji and Hagiwara met in 1962 and planned coordinated research on the prediction of earthquakes. In April 1969, a committee for earthquake predictions was formed so that the information from various departments participating in the research could be exchanged and some conclusions drawn.

By studying conditions during previous earthquakes and the damage they caused, nine different places were declared as special cases and it was decided to take detailed measurements in these regions. They included eastern Rokkaido, western Dewa, northern Nagano, the southwest part of Niigata, the southern Kanto region, the Tokai region, near Biwa Lake, the Hanshin region, the eastern part of the Shimane prefecture and the Iyonada or Akinada region. If any abnormal phenomenon occurs in these regions, readings are taken with extra precision.

The factors responsible for earthquakes are largely unknown, but many believe they are due to dislocation. That is, because of the convection of the earth's core, heavy pressure builds up on the crust and the surface becomes fractured. If the crust is brittle at some point, wraping increases and the crust ultimately ruptures. This is known as an earthquake. Hence, to forecast an earthquake it is necessary to first detect the deflection in the earth's crust and then to measure the changes in it. For that purpose, the measurement data of the National Geological Survey were used, the precision was improved and, by repeated readings, the movement of the earth's crust was closely observed.

The earthquake itself must then be observed in detail. The principal earthquake zones have been defined. If the earthquake waves are measured and analyzed, the internal structure of the earth can be analyzed for future use in predicting earthquakes. Observations of earthquakes are still made by the Meteorological Bureau, but much more rigorously than before.

Earthquakes vary in strength and the weaker they are the more frequently they occur. If small quakes are also measured, ample data will be available for research. Since universities decided to study small quakes, research on earthquake prediction has advanced. The Geodetics Conference held in 1973 recommended to the government further strengthening of research in this direction.

Research on forecasting earthquakes is underway in the USA, the USSR and elsewhere. Scultz of the USA has recently offered a convincing explanation of the structure of earthquakes and has suggested that it may be possible to predict them.

According to him, as the pressures build up within the earth and warping increases, many small cracks develop. If water enters these cracks, the strength of the earth's crust suddenly fails and this collapse leads to an earthquake. When the cracks develop, propagation of quake waves is slow unless water enters these cracks--which results in rapid propagation. Accordingly, if the propagation speed is constantly observed, the changes will help us predict the occurrence of an earthquake.

THE HIGH PROBABILITY OF EARTHQUAKES

Research on earthquake prediction is progressing gradually, but at the present stage, unlike typhoon forecasting, it is more realistic to say that actual prediction is not possible. Accordingly, the first step in prevention of damage is to build fireproof and shockproof houses. Overlooking the economic dimension, it is technically possible to build completely fireproof or shockproof houses. However, in actual fact it is an almost impossible task. Severe earthquakes occur rarely and it may be inconvenient to our daily life to live in houses that are perfectly fireproof and shockproof. And, assuming that we do build such houses, after a great earthquake we may disregard the danger of the next one. Daily convenience always becomes prominent and countermeasures against earthquakes may be neglected. Hence, safety and convenience in daily life are basic parameters and must be included in any new policies. Architectural standards help to ensure safety norms are followed. In constructing a house today, one must conform to the laws regarding strength, fire resistance and size.

These considerations are based mainly on the probability of future earthquakes. The value of this probability must be determined because an earthquake is a very rare phenomenon and there are no accurate long term records. Many pioneers in this field have studied the records of the past and the data from records of earthquakes in Tokyo are presented in Table 20.

This table suggests that a severe earthquake occurs on an average of once every 70 years. This does not mean that the next earthquake will occur exactly 70 years after the first one, but only that the average gap has been 70 years. An earthquake may occur after 300 years or the next year.

We can assume that the probability of an earthquake is the same for each year and that it is a purely random phenomenon. With these assumptions, if we take the period of re-

Table 20. Record of earthquakes in Tokyo

Day	No. of dead and lost	Houses destroyed and burned
July 30, 1649	Many	Many
December 31, 1703	523	20,000
December 7, 1812		Many houses destroyed
November 11, 1855	7,000	64
September 1, 1923	142,800	576

occurrence of an earthquake as τ, then the probability that an earthquake will not occur τ years after the last occurrence is statistically given as $(e^{-t/\tau})$. Thus, the probability of the occurrence of earthquake τ years after the last one becomes $(1 - e^{-t/\tau})$. Since the period of reoccurrence of earthquakes in Tokyo is 70 years, we calculated the probabilities of earthquakes in a ten-year period, as shown in Fig. 23.

The probability that an earthquake will occur after ten years is 13% and after 50 years 51%, but after 200 years it is as high as 94%. Thus, the probability that an earthquake will or will not occur is the same 50 years hence. But after 200 years, its occurrence is almost certain, with 94% probability.

Here we have assumed that earthquakes occur randomly, but according to Kawazumi Hiroshi there is some periodicity in their occurrence. This is because an earthquake removes the warping within the earth's crust and another quake need not occur for sometime. Due to movements in the earth's crust the warping accumulates gradually and the possibility of an earthquake again increases. These factors are repetitive in nature, thus exhibiting periodicity. It is said that earthquakes occur at an interval of 60 years in the Kanto region. If this is true, an earthquake should be predicted for the 1980s. If we assume that earthquakes occur in a very random fashion, the probability that one can occur within ten years is 13% and within 20 years, 25%. There is presently no way to verify this, but we note that either way, the probability that an earthquake will occur in the Tokyo region during this century is quite high.

While designing and constructing buildings the magnitude of the earthquake should be expressed in numerical terms. Kawazumi Hiroshi has studied this problem and determined the expected magnitude of earthquakes that may occur in various parts of Japan. Fig. 24 shows the geographic distribution of earthquake magnitude in each place, based on a 100-year average. In this figure, GAR is the acceleration of vibration and as its value increases the earthquake becomes stronger. When this acceleration exceeds the value of two GAR, many people will be aware of the movement and if it exceeds 250 GAR houses will collapse and be destroyed.

This figure suggests that the danger value of the earthquake differs from region to region. It is very high for southern Kanto, Tokaido, Kinki and others whereas for Hokkaido, Kyushu and others it is less.

But these alone are not countermeasures for earthquakes. In crowded cities the danger of fire due to house collapse is

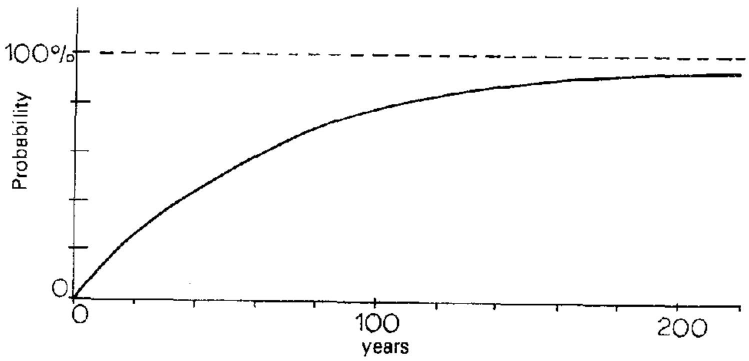


Fig. 23. Probability and period of great earthquakes in Tokyo (period of reoccurrence is 70 years).

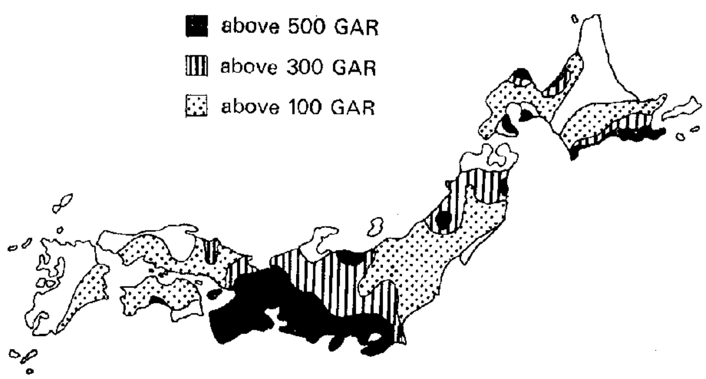


Fig. 24. The maximum seismic intensity of earthquakes occurring at least once every 100 years.

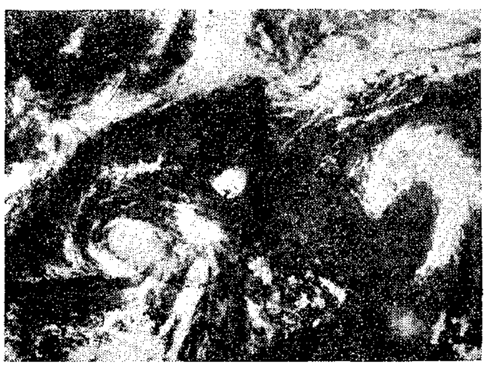
equally great. Without fire accidents the total damage would have been only 10% of the actual value. When earthquakes occur, fire fighters are too few, however hard we try to alter this.

When an earthquake shakes the region it is absolutely impossible to prevent the destruction of houses by fire. However, it is better to lose material wealth and save human lives. It may be necessary to construct refugee camps and alternative roads as a precaution. Unfortunately, big cities are expanding indiscriminately and ignoring such precautionary measures. These problems are difficult to solve since they also relate to problems of space, but some adequate countermeasures must be found in the near future.

When an earthquake occurs we must all react responsibly to avoid further disaster. When the earth shakes, communication links and firefighting equipment may be damaged. Individuals will only be able to save themselves if they marshal their presence of mind. During the Kanto earthquake, a rumor spread that a rebellion had occurred and many people believed it. Rumors spread according to their relevance and credibility. If each individual is knowledgeable about earthquakes and is mentally prepared at the time of the earthquake, additional misery can be avoided.

Chapter Twelve

Natural Disasters



Weather photograph taken on August 27, 1970.
Left groove--Typhoon 11
Central circle--Typhoon 12
Right arch--Low pressure.

A spring breeze is blowing,
But people,
Punished by nature,
Are spending restless nights.

Hakyo

The flood water spread,
And people,
Making a bonfire,
Protected the banks.

Tsukitosh

The autumn winds carry over
The stones
Thrown away by
Erupting Asama.

Basho

In the chilly winds of winter
Women and children
Are eating alms
In the temples.

Buson

The deep snow
In the fields of Michinokh
Forces people
To sell their women.

Seiton

With the arrival of floating ice
Tides at Soya
Are very rough
And do not get calm.

Seishi

[These poems are typical Japanese compositions called "Haiku". They reflect the theme of this chapter, showing how people lead a miserable life when ravaged by nature--Translator].

EXTENT OF DAMAGE

Japan faces frequent natural disasters. In his lifetime a Japanese suffers at least once from some natural calamity. I myself remember many such calamities. When I was four years old we lived in front of the Ofudosama in Fukagawa in Edo Ward of Tokyo. One midnight, we were rushed to the second floor of the house because of great floods. The surrounding single storied houses were severely damaged. Short-circuiting of electric wires produced the crackling noise of fire crackers and we heard that further away fires were erupting.

I can recall no heavy rainfall but the flooding was due to high tides in Tokyo Bay. This incident occurred on october 1, 1917. Records of that time reveal the presence of a typhoon of central index 950 mb rising from Izu, passing the western side of Tokyo and traveling up to the northeast region. The high tides were due to this typhoon which ultimately moved out into the Pacific Ocean. The barometer reading exceeded 2.30 m. In the heavy damages 1342 people died or were missing, 36,459 houses were completely destroyed and 2442 houses were damaged by the tides.

The second disaster I witnessed was the great Kanto earthquake in 1923. Another earthquake occurred on May 16, 1968 in Hokkaido near Tomakomai, off Tokachi.

How much damage do natural calamities cause in Japan annually? This is difficult to estimate. The objects of damage are distributed throughout the country, the methods for surveying them are not standardized and the data are inadequate. The damage may be direct or indirect and it differs depending on the source of damage, the objects which are damaged and the economic condition of society.

Using such records as those prepared by police department and other officials, the average value of damage per year is shown in Table 21.

The extent of damage changes significantly with each fiscal year. Earthquakes and tidal waves in particular vary annually. For example, the average will differ by almost a digit depending on whether or not we include the damages resulting from the great Kanto earthquake. In contrast, yearly damage caused by fire does not vary very much and damages due to storms and floods are also fairly constant. The level of damage changes as countermeasures against such calamities are more wisely applied. Considering these points a period was selected so that the average condition resembles that of 1960.

Table 21. Average value of damage due to disasters

Types of disaster	No. of dead and lost	Houses destroyed, washed away or burned	Period
Storms and floods	2067 (8%)	9746 (26%)	-
Typhoons	740	8336	1955-64
Heavy rain	290	866	1955-64
Others	356	544	1955-64
Sea disasters	681	-	1954-63
Earthquakes and high tides	4260 (17%)	18426 (49%)	1920-64
Accidents at work	4669 (19%)	-	1959-63
Traffic accidents	11749 (47%)	-	1959-63
Railway accidents	1225 (5%)	-	1959-63
Fire	791 (3%)	9337 (25%)	1959-63
	24761 (100)	37549 (100)	

Table 21 includes man-caused calamities such as traffic and railway accidents. The number of persons dead or lost is 24,761 or 3.5% of the total annual deaths, 700,000. Damage due to man-caused disasters is a large proportion while deaths due to natural disasters are about 28%. Among the natural disasters, the biggest factors are earthquakes and tidal waves, next storms and floods and then fire accidents.

In the calculations in the table, we include the losses caused by the great Kanto earthquake. If we omit these, the average damage is reduced by two-thirds and the above sequence changes. Some people suggested omitting these data, but if we wish to consider the characteristics of damage caused by earthquakes and tidal waves, then we must include them.

The number of houses damaged within a year was 37,549 or 7.5% of the total number of houses (500,000) built during this period. Earthquakes, tidal waves, storms and floods and fire, respectively, cause the most damage. Other factors also affect damage to houses such as partial destruction, partially burned portions, seepage water and so on but these have not been included.

It is much more difficult to estimate losses in terms of money than in numbers of dead and missing or in terms of numbers of houses damaged because there are many indirect effects (traffic jams or difficulties in the production of goods) in addition to the direct effects of disaster in a natural calamity. We therefore cannot arrive at an exact estimate of the damage done. However, damages from the direct effects are given in Table 22.

In the table all monetary values have been given in 1960 values.

The total damage according to the 1960 monetary value was about 185.7 billion yen or about 1.6% of the GNP which then was 11800 billion yen. Storms and floods accounted for 44 sources of disaster. This changes, however, when we consider the number of dead and missing or the damage to houses. The sequence of objects destroyed is: houses, crops, public buildings. Public works are generally under government maintenance and if we include other works, the total may increase by 50-100%. From any point of view, the total annual damage due to natural disasters throughout Japan is about 200 billion yen which is 1.8% of the GNP and about 10% of the national budget.

Is this figure large or small? Efforts have been made to prevent damage and had we not done so, the amount of damages might have been much greater. High population density and concentration of property are important contributory factors to this heavy damage. If rivers in an uninhabited region rise and the water spreads over a wide area, there may not be any monetary loss. If a violent storm rages in the middle of the Pacific Ocean, there will be no damage except to ships which happen to be there.

It seems then that if the economy prospers, property also increases but this results in an increase in damage. Disasters are not just a matter of natural phenomenon, but are defined in terms of human activity. Herein lies the difficulty in framing countermeasures to natural disaster.

PERIODIC CHANGES IN DISASTERS

As the condition of society changes, the nature of disaster also changes. Some types of disaster become less important and others become more important. Table 23 divides damage into eight types including storms and floods, long spells of rain, dry spells, drought, epidemics, volcanic eruptions, earthquakes and fires. The table was made by Arakawa Hidetoshi who studied the frequency of disasters over one hundred year

Table 22. Estimates of average damages due to natural disasters
(As in 1960, in 100 million yen)

Source of damage	Houses	Public buildings	Crops	Forestry and Fisheries	Transport	Others	Total
Earthquakes and high tides	285	140	-	2	5	30	462 (25%)
Storms and floods	130	190	200	200	80	20	820 (44%)
Cold or dry spells	-	-	220	-	-	-	220 (12%)
Fire	115	-	-	-	-	240	355 (19%)
Total	530	330	420	202	85	290	1857 (100%)

Table 23. Periodic changes in the type of disaster

Period	Frequency of disasters	Storms and floods	A long spell of rain	Dry spell	Drought	Epi-demics	Volcanic eruptions	Earth-quakes	Fires
651-700	21	0	2	24	24	15	10	10	10
701-800	154	3	5	20	36	22	6	6	3
801-900	221	5	12	18	28	13	8	7	9
901-1000	168	7	16	29	8	18	4	3	16
1001-1100	113	4	4	23	8	19	4	6	32
1101-1200	85	9	11	19	9	24	6	5	18
1201-1300	128	6	11	21	9	19	7	9	18
1301-1400	97	9	8	21	10	25	10	10	6
1401-1500	145	7	5	21	17	20	8	14	8
1501-1600	159	7	4	16	21	13	17	13	8
1601-1700	326	19	7	19	12	6	14	14	9
1701-1800	392	18	10	19	16	8	12	11	7
1801-1900	383	15	10	19	11	9	15	13	7
1901-1950	168	23	4	9	4	11	25	10	14
1951-1964	49	29	4	4	6	0	25	16	16

periods. The values shown here indicate the relative frequency of each type of disaster. Since 1900, these data have been divided into two parts: 1900-1950 and 1951-1964.

The earlier data are less reliable because the records are not accurate. To overcome this problem, we have shown the relative values. Even this is not a fully accurate method but the trends are apparent. For example, damage due to floods and storms increases with time, the number of dry spells decreases and the number of volcanic eruptions increases. Famine was more frequent around 800 and 1600 A.D., whereas fires during those periods were very few.

These variations reflect changes in society and climatic changes. Disasters occur as a result of the struggle between man and nature. If man's resistance to nature's violence increases the disaster will be limited, whereas if nature's violence increases, the damage may also increase.

In ancient times, losses due to dry spells were greater than those due to storms and floods. This was because irrigation was not as highly developed as it is today and heavy losses were incurred if there was a long dry spell. Since the population density was low and people used to build houses in safe places, storm and flood damage had less impact. Modern medicine has enabled man to control epidemics but volcanic eruptions have become more frequent and with increased population the probability of being affected has also increased. Drought and fire seem to have a cycle of 800 years and it is believed that this is mainly because they are affected by changes in weather.

Let us analyze change in the degree of damage. This is possible since we have data about damage from storms and floods from the Showa period. Fig. 25 shows the annual number of dead and missing, of houses washed away by floods and of floods. The vertical axis is calibrated on a logarithmic scale.

These factors change greatly every year since the strength of typhoons and the amount of rainfall change every year. If a typhoon is very strong, damage will be severe and this is apparent in the graph. If the population or the number of houses changes then the level of damage would be expected to change accordingly. These factors make it difficult to assess change, but damage has shown a tendency to increase between 1935 and 1955.

Let us put this into a mathematical formula. Generally in Japan, the extent of damage due to floods and storms depends on the strength of a typhoon. Damage (D) can be

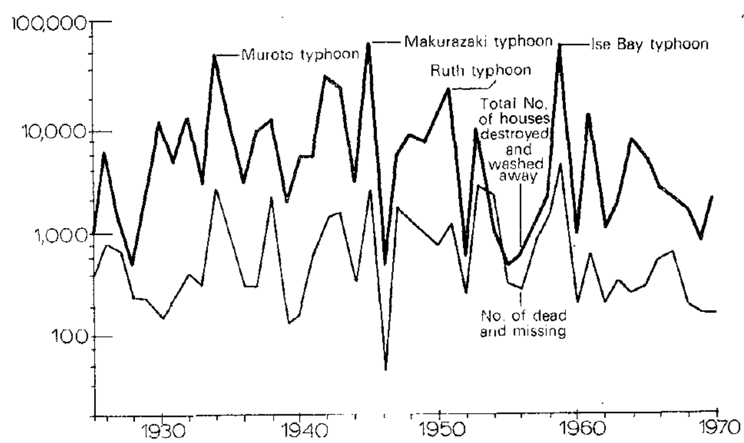


Fig. 25. Changes in damage due to floods and storms.

expressed in terms of typhoon strength as shown in the following equation:

$$D = C \cdot N \cdot I.$$

Here, N is population, I indicates the strength of the typhoon and C is an index which changes according to the preventive measures taken. The preventive measures and the population change comparatively slowly and the short term changes in damages are determined by the strength of the factor causing them. However, long term changes in damage are controlled by all three factors, C, N and I.

The actual magnitude of damage is the combined result of these three factors. Let us analyze the effect of each factor individually. First, since damage is proportionate to the population, we will transform the population for each year to that of 1960. Then, disregarding damage due to typhoons less than 965 mb in strength, we can determine the relationship between damage and the strength of a typhoon. (We disregard the weaker typhoons because the damage caused by them is greatly reduced by effective preventive measures and in such event the impact of the typhoon is reduced.) Using this relationship, we can calculate the estimated damage of a strong typhoon and then compare it with the actual figures. When both figures match, C is indicated, that is, the level of preventive measures. Since many other factors affect the results, our figures cannot be exact, but we are accurate to one decimal. Table 24 shows the values calculated according to this formula.

Table 24. Periodic change in damage due to storms and floods compared with standard damage

Years	No. dead or lost	Houses destroyed or washed away	Standard figure
1931-35	0.5	0.3	3
1936-40	0.7	1.5	1
1941-45	2.7	3.2	3
1946-50	3.6	3.1	5
1951-55	3.2	2.1	3
1956-60	1.5	0.6	3
1961-65	0.1	0.4	3

Preventive measures are also greatly affected by war. During World War II, damage increased to three times the standard damage. Recently, however, damage has decreased remarkably, to half the standard damage.

During World War II weather information was inaccurate, the general public was not concerned with weather conditions, there were severe shortages and preventive measures were inadequate. Therefore, a typhoon caused five to ten times the amount of damage as one of similar strength in the early Showa period. As conditions returned to normal after the war, damage again began to decrease and today, even though a high degree of economic growth has been achieved, damage has been reduced to one-tenth that in wartime.

The danger to human life has also been reduced, mainly because meteorological techniques have improved. The mass media are well developed and weather alerts can be widely broadcast. Evacuation systems are also well developed.

Nonetheless, no method of preventing the damage from extremely heavy rains has been developed. These heavy rains fall only within a narrow area and they are very difficult to predict. With increasing population pressure and the pressing demand for more housing, hills have been destroyed to make space for houses and, as a result, damage due to landslides has increased. Kurashima Atsushi has examined the frequency of heavy rainfall for different years. According to him, the frequency has increased since 1950.

It appears, then, that preventive measures against storms and floods should focus on the problem of heavy rainfall instead of typhoons which is the main concern today.

Table 25. Frequency of initial heavy rains causing more than 100 casualties

Year	Frequency
1920-29	-
1930-39	4
1940-49	2
1950-59	6
1960-69	5

One reason that the damage due to floods and storms increased since the war is that conditions now favor strong typhoons such as the Makurazaki typhoon, Ice Bay typhoon, second Muroto typhoon, Typhoon Ruth and others. This is because of changes in climate. As a result, damage due to storms and floods has increased to about three times prewar damage. The effect of weather changes is therefore significant.

A MODEL OF PREVENTIVE MEASURES

Let us examine a model which may serve as a guideline in preventing natural disasters. A disaster is a complex phenomenon and primarily an economic problem. For example, funds are required for preventive measures against typhoon damage but if the amount of damage from the typhoon is less than the amount required for prevention, the preventive measures can be abandoned.

Let us assume that the damage from a typhoon is proportionate to the third power of its intensity. For convenience, let us assume that one typhoon occurs in a year and that the probability of its intensity being greater than a certain value can be discerned from past records. We can assume that probability decreases exponentially as the intensity increases. These assumptions are fairly realistic.

It is possible to prevent damage entirely when the strength of the incoming typhoon is within a certain level, but when it exceeds that limit it is assumed that the preventive measures have no effect. The funds necessary to prevent typhoon damage are assumed to be proportionate to the intensity of the typhoon.

The above assumptions are shown in Fig. 26 using some model values. The dotted line indicates the probability that the typhoon exceeds certain intensity and the thick line indicates the sum of the expected losses due to damage and the expenditure necessary for preventive measures. This mean value indicates that if the intensity of the typhoon is high the value exceeds more than 100%. This is because damage due to the typhoon is not severe and the only loss is due to the amount spent for preventive measures. If the damage is not below a certain level, then the expenditure drops suddenly. In Fig. 26 this phenomenon occurs at a value of 910 mb after which it increases again. This is because when the intensity of the typhoon drops below this level, the probability of appearance becomes very low. Accordingly, the expected amount of damage also decreases and the cost of preventive measures increases. Changes around the minimum value are very small. For example, if preventive measures aim at a central pressure value of 920 mb to 895 mb, the changes are not significant and the optimum value can be discerned by considering more constraints.

In this model we have considered only the damage due to typhoons but a similar model can be used to analyze damage due to heavy rains or floods. In framing preventive measures

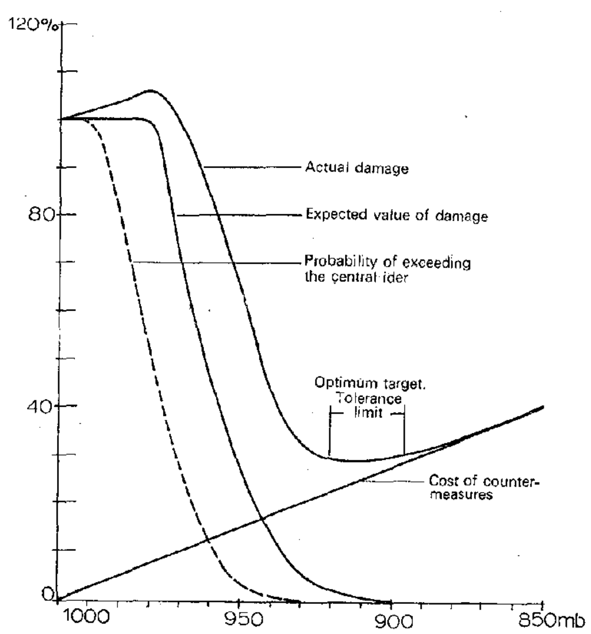


Fig. 26. The intensity and damage caused by typhoons.

against natural disasters, the following should be considered:

1. If the preventive measure is not correct, the main loss will be due to the measure itself;

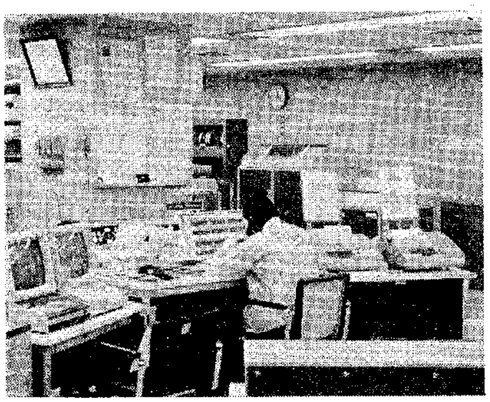
2. the optimum target value can be placed at any point and this value will be treated as a guideline in determining the appropriate cost of preventive measures;

3. this optimum value is determined by the probability of a natural disaster occurring in addition to such economic factors as the probable degree of damage, the cost of preventive measures and so on.

These considerations are based on tentative figures since they are estimated according to a very simple model. We are not sure to what extent these figures can be useful. For example, human lives have not been assigned a value and the result may vary accordingly. However, avoiding natural disasters is not simply a matter of science and technology, but has economic and political ramifications too. An overall evaluation of this problem is still awaited.

Chapter Thirteen

The Role of Information



Automatic compiling machine for collection of world weather data.

To understand the cooperative nature of communities such as those of ants, it is necessary to discover the channels of communication among the ants themselves!

Weiner
Cybernetics

RUMORS AND THEIR CONSEQUENCES

Information is essential for modern society. Ignorance leads to insecurity, social instability and confusion. For example, during an earthquake, a disaster that cannot be predicted, rumors spread rapidly, causing insecurity in society. During the great Kanto earthquake of 1923 there was a rumor that a rebellion had occurred and that many people had been killed.

Rumors spread during calamities and such extraordinary conditions as war can have serious consequences. According to the book coauthored by Orpoult Postman, *Psychology of Rumors*, the circulation of rumors is proportionate to their degree of importance and vagueness. That is, the circulation of rumor = (gravity of consequence x vagueness). This equation is confirmed by our experience.

Among natural disasters, storms can be predicted the earliest and the information communicated through television, radio and so on. Sudden surprise is therefore not a factor. On the other hand, calamities such as earthquakes are very difficult to predict and because the available information is not adequate, rumors spread easily. According to the above equation, even during disasters such as storms, if sufficient information is not available, rumors will start spreading. Past records suggest that during the Tokegawa period, there were many such incidents. For example, according to the records of Nagasaki town office, there was a flood due to heavy rains on June 6, 1796. A rumor then spread that these floods would recur and the couple who started the rumor was punished.

To avoid the spread of rumors during times of disaster, it is necessary to provide sufficient and correct information to the general public. This is one of the reasons that the meteorological department exists on a national level. The main responsibility of this department is to inform people about natural disasters and to give them sufficient warning.

PSYCHOLOGICAL IMPACT OF WEATHER BULLETINS AND PRESS COVERAGE

Even when information is correct, we must consider its psychological effect on society once it is delivered to the public. For example, weather information must be properly presented or it will not be understood. The information demanded by the public may not be the same in emphasis and detail as that needed by the weather bureau. The weather bureau knows from experience the value of its information and while publishing it this value is considered.

How can the psychological value of weather information be calculated? Although not simple, the task is not impossible. For example, the information published in the press is one measure of its value. The higher the psychological value, the greater its elaboration, that is, the amount of coverage increases accordingly.

We studied the amount of weather information published in newspaper 'A' from 1965 to 1967. To determine the amount of information, the number of words in the report should be counted, but as this was too cumbersome the printed area was measured. Within 1 cm^2 about 11 letters can be printed. From this we can determine the actual number of words, that is, the amount of information. If the area of the report is large then the amount of information is large and it appears that this information has a higher psychological value. Table 26 shows the amount of information on different types of important climatic phenomena. Usually a single report contains 3100 letters. The amount of information is represented here in terms of this standard unit.

According to the table, the greatest amount of information is published on typhoons, about 50% of the total information on climate. The amount of information appearing at one time is also greatest for typhoons, about 12.5 times the standard report.

Heavy rainfall at the end of the rainy season receives the next highest amount of publicity, about 20%. The average report on this topic is about 4.6 times the standard report.

Third is reports about snowstorms or heavy snowfall during the winter, accounting for 8.3%, with the amount of information at one time 3.2 times the standard report.

Thunderstorms occupy fourth place, accounting for 2.5% with the amount of information about 2.2 times the standard.

These are the most important weather bulletins in the newspapers. They contain larger amounts of information, indicating a higher psychological value. The table also suggests that if a phenomenon results in casualties, destruction of houses or the washing away of property, the report is larger.

Figure 27 shows the relationship between the number of dead and missing and the space given to the report. Here, both *X* and *Y* axes are plotted on a logarithmic scale. The points are quite random, but they indicate clearly that as the number of dead and missing increases, the report occupies a larger space. This area is also proportionate to the number of dead and missing. Thus, the number of dead and missing can be used as an index of the psychological value.

Table 26. Amount of information and the content of weather bulletins

Content of information	Total area (cm^2)	Percentage	Repetition (times)	Amount of information per person (proportionate to standard)
Typhoons	49,514	50.2	14	12.5
Heavy rain	19,266	19.5	15	4.6
Rain	1,506	1.5	5	1.1
Rain with lightning	2,521	2.6	4	2.2
Heavy snowfall, snowstorm	8,155	8.3	9	3.2
Snow	777	0.8	3	0.9
Snowslide/avalanche	282	0.3	2	0.5
Hailstorm	60	0.1	1	0.2
Strong winds	1,121	1.1	6	0.6
Indian summer or autumn rain	992	1.0	4	0.9
Fog or smog	1,734	1.8	8	0.8
Sudden fall in temperature	1,881	1.9	8	0.9
Prediction of Sakura	198	0.2	2	0.4
Sudden rise in temperature	2,221	2.3	7	1.1
Others	942	1.0	8	-

If we study damage to buildings we find that the length of the report about the disaster increases as the number of damaged houses increases. The increase is not linear but inversely proportional, that is, even if the damage is more severe, the volume of information about it is not commensurate. Thus, the loss of human life increases the value of information to a greater extent.

The same phenomenon is apparent in a different survey. If a disaster is severe, the meteorological department publishes various bulletins as records and as background material for planning preventive measures. They grow thicker as the disaster becomes more severe. For clarification, we studied the relationship between the magnitude of the disaster and the size of the bulletin relating to it, or the number of pages of the bulletin. In Fig. 28, the size of the disaster is indicated by the number of dead and missing on one axis and the other axis indicates the number of printed pages. For convenience, both the *X* and *Y* axes are plotted on a logarithmic scale. During World War II, and for sometime afterward, printing was done in a compact manner due to a shortage of supplies; hence the number has been multiplied by three. In Fig. 28 the classification is made on the basis of the source of the disaster and three sources, typhoons, heavy rain and earthquakes and tidal waves, are considered.

Even though the points are random, they indicate that the number of pages increases as the disaster becomes more acute. The relationship is similar for all types of disasters. If the number of dead and missing is less than 30, a printed report is not published; if the number is greater than 2,000, the number of pages of printed matter increases greatly. Thus, human psychology or the reaction of society to a disaster, is a multiphased phenomenon. If we divide the information on natural disasters into two parts, warning and alarm, we find some points in common. The degree of damage (which is the distinction between the two) and the abnormality of the weather are shown in Table 27.

If the number of casualties is greater than 60, society's reaction increases greatly and if it is more than 1,500, it increases acutely. Again, if the number of destroyed and washed out houses is more than 500 and 15,000, respectively, similar reaction is observed.

THE IMPACT OF PREDICTIONS

Leaving aside the psychological value of information, let us

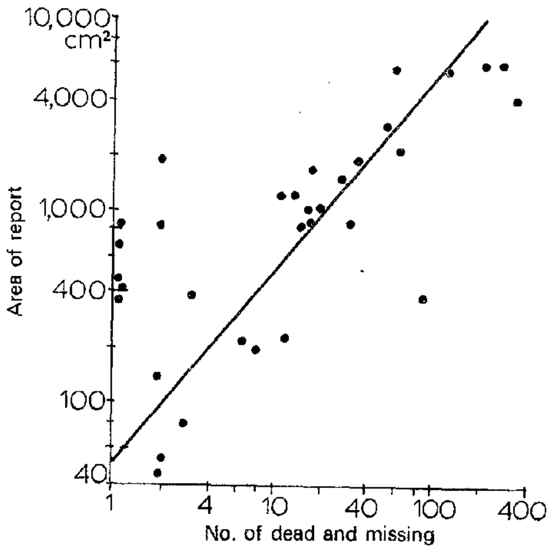


Fig. 27. Number of dead and missing due to floods and storms and the area of the floods.

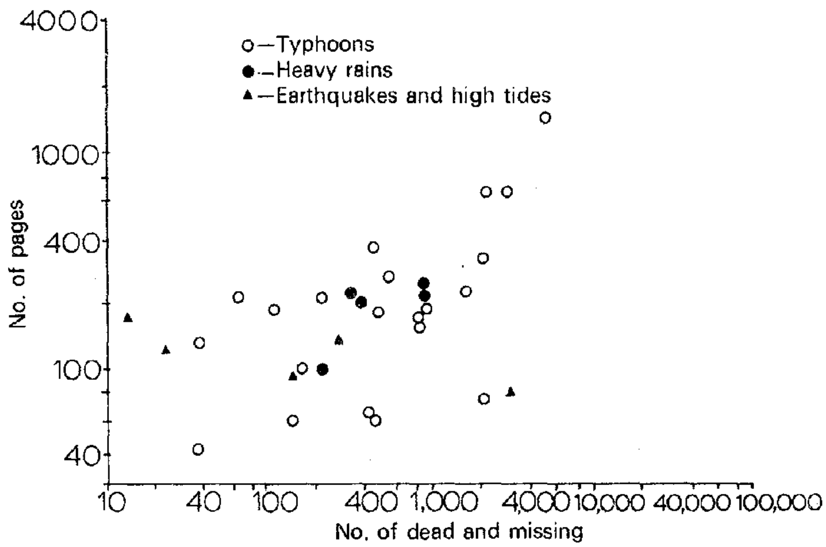


Fig. 28. Magnitude of disaster and the abundance of reports.

Table 27. Stages of social reaction to disaster

Stages	No. of persons dead or missing	No. of houses destroyed or washed away	Rainfall per day (mm)	Maximum wind speed (m/sec)	Central air pressure of typhoon while landing (m.b.)
First stage	60	500	170	321	980
Second stage	1,500	15,000	400	45	930

analyze the effects of prediction. Prediction is a very difficult task. It is not easy to analyze a phenomenon of the past, but a prediction is even more difficult. This is because initial errors in the prediction accumulate and their effect expands.

Particularly in economic forecasts, used to plan future courses of action, if the bases of the prediction change, the prediction cannot be accurate. In such cases, it is sometimes better to make false predictions. For example, when the economic condition is expected to be bad, if proper preventive measures are adopted, business may not get worse. Under such circumstances, a false economic prediction can be advantageous.

On the other hand, in weather forecasts, the climate is not going to follow the forecast since the controlling factor is nature. Accordingly, if the prediction does not come true, it is of no use.

The weather significantly affects our daily life and so people are very interested in weather forecasts. A great deal of research has been conducted to improve the accuracy of prediction and some improvement is noticeable. However, even though science and technology have advanced greatly, the percentage of correct predictions is not sufficient. The weather forecast for the next day is incorrect about three times a month.

While research proceeds, many problems must be overcome. Therefore, we cannot expect weather forecasts to be 100% accurate. At the same time, there is still scope for improvement in the utilization of this information.

Let us consider the prediction of typhoons. It is not easy to accurately predict the arrival of a typhoon at a particular location. The percentage of accuracy of the prediction that a typhoon will arrive at a certain location varies in each case, but generally predictions are 70-80% correct. Accordingly, preventive measures based on such predictions may be unnecessary in 20-30% of the cases.

We emphasize here that the value of a prediction cannot be determined only by the degree of accuracy. The accuracy of a prediction may be high with certain information, but the information itself may not be so valuable or the vital information may not be accurately predicted. Let us assume that a prediction says a typhoon will not reach a certain spot. The accuracy of such a prediction based on the yearly averages may be higher than 99%. However, this information is not very valuable. If the typhoon does not usually hit that spot, there is no great value in predicting that this time it is not going to hit it either. On the other hand, a prediction that a typhoon will arrive tomorrow is more valuable even though the accuracy of the prediction is only 50%. In such cases, preparation may be unnecessary one out of two times, but preventive measures will have avoided damages when the calamity does occur.

Weather forecasts are made to avoid the ill effects of changes in climate. If there is no ill effect, such a prediction is not required. The actual effect varies with the objects that are affected and with the climate. Clear skies are usually taken as good weather but during a draught they are not desirable. Thus, the content of the weather forecast is utilized differently depending on the person using it. It can be useful even when the percentage of accuracy is low and high accuracy may accompany rather useless information. The weather forecasts delivered by meteorological agencies or observatories are meant for the common man. Hence, all factors may not be included and on some occasions they may not be satisfactory. For specific predictions a special request should be made to the weather office.

The effects of prediction are explained in further detail in the simple model below. The typhoon is a type of disaster which causes heavy damage. Let us take the value of damage as L. Once a typhoon warning is received, some damage can be avoided through preventive measures. All damage cannot be prevented, but for convenience let us assume that it is. In this case, we can add the actual damages to the costs of preventive measures C.

Now let us assume the accuracy of the prediction as P. If no warning had been received, the total damages would have been $P \times L$, whereas if preventive measures were taken, it would cost C. If $P \times L$ is smaller than C, it is better not to forecast a typhoon as preventive measures are not necessary. On the other hand, if C is less than $P \times L$, a warning should be broadcast as it would have some value. We can thus say that when C is small, the warning is useful even though the accuracy is not very high. Otherwise, the forecast is not useful unless it is very accurate.

We have discussed the value of the warning: "typhoon not coming" and the prediction will be quite accurate, but we cannot guarantee that the prediction will always be correct. Let us take this accuracy as P. If the prediction is wrong, there will be heavy damage and this must be noted in considering the value of the alarm. Doing so, the value of the warning again changes. Omitting the intermediate steps, we can find the value of a warning from the following conditions:

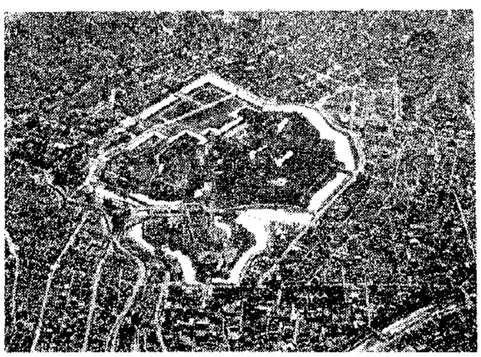
$$P > C/L > (1 - P')$$
$$P > W > (1 - P').$$

Here, W is the meteorological probability of a typhoon arriving. This value is very small when we consider the case of an arriving typhoon, and hence, unless the accuracy of the prediction that a typhoon is not going to come is almost one, the warning has no value. P' is not always near one and therefore there have been incidents in which the value of the warning decreased. Today, because of the network of observations and weather satellites, P' has almost reached one and as a result there is no chance that the value of a warning will approach zero. The value of warning that a typhoon is arriving is determined by the relation between the accuracy of prediction (P) and the economic condition (C/L). Thus it is not only accuracy, but the economic factor which needs to be considered.

To be more specific, the accuracy P or P' changes as the initial pressure distribution changes, even though the technical standard of the prediction is the same. There can be prediction that the typhoon will certainly arrive and there can be a prediction that under normal circumstances the typhoon will not arrive. If we know the accuracy of such a prediction, we can compare it with C/L. If P is bigger, then preventive measures should be applied; if P is smaller, they should not be applied and the initial value of the damage can be reduced. Thus, by studying the way a warning is delivered and the way it is utilized, the effectiveness of the warning system can be increased even though the technical standards of warnings remain the same. No research on this subject was conducted in the past, but now that weather forecasts are used at all levels of society, these data could be very useful.

Chapter Fourteen

National Planning



Aerial view of central Tokyo.

It is not the lack of understanding on the part of common men which arrests the advance of science, but the utter ignorance of a clear vision of their mission towards science and its essence on the part of the scientists that comes in the way of scientific advancement.

Terada Torahiko
Material and Words

THE IMPORTANCE OF PLANNING

To feed a large population in such a small country, land must be utilized in a planned way. A national plan serves this purpose. A national plan is not a new idea; plans were used in the Nara and Heian periods. At that time the plans did not cover all of Japan as they do today, but were limited only to the capital cities. In the feudal system of the Tokugawa period each clan had its own plan, but during the later half of the Meiji period plans were viewed from a national perspective. The real implementation of national plans began only after 1940.

Just before Japan entered World War II industrial planning became the center of planning activities as preparation for war. The term National Plan became current at this time. Ishikawa Eiyo, an authority on the topic, has defined the national plan as an activity to expand the national contours and has said that it includes such aspects as: 1) the distribution of population; 2) the location of industries; 3) the development of culture; and 4) national defense.

Today as population pressures increase, national planning has become more important and as a result the National Development Act, the Hokkaido Development Act and others were passed in 1950. In 1972, Tanaka Kakuei published a paper, "Improving the Islands of Japan," which received great public attention.

To prepare a detailed blueprint of the national plan, some perspective is necessary which can serve as a basis. This should be supported by surveys and the actual work should begin only after general conclusions have been made. It is therefore a very difficult task. It is not easy even to prepare an outline, and while it may be beyond the scope of the common man, I wish to introduce the idea of national planning here.

PER CAPITA LAND REQUIREMENT

While designing the national plan, we must know how much land is required for one person to earn his living. Space on earth is limited. Japan covers only 0.25% of the total space available on earth, but 2.8% of the world's population lives here. If land resources were limitless, the population could have grown unchecked. But faced with these limits of land, the population should reach an optimum level at some point. This optimum point varies with the natural environment, production developments, standards of living and the area of land available. We must examine these considerations to determine land requirements for one person.

In Tolstoy's story "How much land does a man need?" a farmer wanted extensive land. Knowing this, a villain promises to give him as much land as he can cover on foot from sunrise to sunset on payment of only 1,000 rubles. The farmer, hoping to secure a great deal of land, crosses a long distance, but then dies of exhaustion. The conclusion is that the amount of land necessary for one person is only that large enough to bury his coffin.

In Japan, an average of 300 calories of solar heat is incident per cm^2. If all this heat can be converted into the food energy necessary for the existence of a man (2400 calories) then 90 cm^2 of land is sufficient. This in fact tallies with Tolstoy's conclusion. However, this is not possible in actual practice. Only a 1000th part of the solar energy can be utilized. As a result a man must have 30 m^2 of land.

Even this is not really enough. To organize a prosperous society, we need some land to prepare goods, for transport, for cultural activities, for recreation and so on. Man does not live independently of nature; all his activities are within the framework of the natural environment. There must therefore be harmony within the system and if we distort it, problems like pollution raise their ugly heads.

Considering these factors, let us try to estimate the area of land necessary for one person using the 1970 statistics as a reference. The shelter required by one person is about six *tsubo*, that is, 20 m^2. This does not include the kitchen, verandah and bathroom. If we include these, it is 25 m^2. While more space might be desirable, this minimum is satisfactory. If we add the land necessary for a garden or park, the figure increases by three times, to 75 m^2. Some land is also required for social functions such as schools, municipal buildings, shops, offices and so on. The number of people concerned with such activities is about 46% of the total population. If this factor is included in defining the amount of land required by one person, it becomes 29 m^2.

If we consider productive activities such as factories or mines and that about 18% of the population is engaged in these activities, then the area required by them is 100 m^2 per person. Converted to the entire population this works out to 18 m^2 per person.

The area of land required for roads, railways and so on is about 15% of the total land area or 20 m^2 per person.

One of the largest uses of land is for farming. The area available is defined by weather conditions, the quality of the soil, the availability of water and so on and cannot be stated in simple terms. As of 1970, the area of farm land required per person was 330 m^2 and if the area required for paddy fields is added, it becomes 500 m^2. Today most wheat and other grains are imported, but if we were to produce these crops locally, the minimum land required to support food production would be 600 m^2 per head. Today, there are still about 100 m^2 agricultural land available for cows, pigs and other animals to graze. This supplies us with animal proteins and fruits from orchards. We supplement these proteins by eating fish from the sea, but this is still not sufficient. A substantial amount is still imported and if we decide to meet the demand from local stock, then about 300 m^2 land would be required.

The total then comes to 1042 m^2 per person. This is the minimum area required to support human life. Table 28 shows the numerical values after analysis.

I have estimated these figures from my own limited knowledge but I believe any error is within a digit. These estimates are based on cities with more than 500,000 people in modern Japan. There are also cities like Sappore where the land requirement comes to 1100 m^2, but in most cities it falls between 70 and 450 m^2 with the standard 130 m^2. If we add figures for housing, public offices, distribution systems, transportation, communications and so on, the requirement comes to 124 m^2 and this tallies roughly with the above figures.

Incidentally, the total area of Japan is 370,000 km^2 of which level land is 18%, that is 66,000 km^2. If we claim only the level land for the purpose of residence, then the population which can be supported according to the calculations of Table 28, is about 60 million, which is only 60% of the present population. Today a substantial amount of food is imported and as less land is required for food, 100 million people can be supported here.

If the land surface of the mountains can be used, a larger population can be accommodated. However, there are many obstacles to use of mountainous regions. First, as the temperature at high altitudes is low, it is difficult to produce good harvests. Second, transport on sloping land is difficult and little land is available for factories or residences. Mountains indeed have their own functions. One is to supply timber, another to supply water to rain-fed rivers. This in turn serves as a source of energy for hydraulic power. Then, too, the trees of mountain forests synthesize carbon dioxide from the atmosphere and help to maintain the composition of the atmosphere. The amount of carbon dioxide annually synthesized

Table 28. Area of land required for one person

Type of land	Necessary area (m^2)		Number of occupants (1970)	
Housing	75		100% (relative value)	
Living		25		
Garden, recreation, etc.		50		
Circulation systems	13		19.1	
Business, finance, etc.		8		11.4
Service, etc.		5		7.7
Production systems	18		17.9	
Metal industries, energy production, etc.		15		13.9
Construction		3		4.0
Transport, Communication	20		3.2	
Government offices	16		26.7	
Government agencies		1		1.7
Schools		15		25.0
Agricultural land (including fisheries)	900		9.9	
Fields		600		
Orchards, meadows		300		
Forest	3000		0.2	
	4042		77.0	

by these forests over all Japan equals 300 million tons of coal.

On the other hand 300 million tons of coal are consumed annually. Accordingly, this is reconverted into oxygen through the forests. If fuel consumption further increases, or if the forests decrease, the purity of the atmosphere cannot be maintained and fuel consumption will lead to pollution. We can neither reduce the forest area nor increase the consumption of the fuel without upsetting this balance.

These factors and the assumption that Japan intends to adopt a policy of isolation as in the Tokugawa period while trying to maintain a high standard of living suggest that the population must be reduced to 60% of the present level. Fuel consumption cannot increase any futher. If we maintain the present population, then living standards must decline. The alternative is a change from our staple rice to Chlorella, indeed a revolutionary idea. In sum, Japan cannot isolate herself today but must consider herself part of one world.

POPULATION REGULATION ON LIMITED LAND

Population distribution is one of the bases of national planning. Society consists of man and his activities. For the production of articles of daily use, man has found it convenient to live in groups. Annual increase in urban population confirms this. However, in countries like Japan where natural disasters are frequent, cities are highly vulnerable to the resulting damage. The damage in Yokohama and Tokyo after the great Kanto earthquake, the damage in Hanshin region due to the Muroto typhoon, the damage in the Tokai region because of the Ise Bay typhoons indicate this. Wide population distribution is also advantageous in terms of production and distribution of food. And certainly any changes in population distribution must be analyzed to ensure that they do not disturb the existing natural balance.

Let us examine this in terms of natural disasters. An area in a radius of approximately 50 km of the exact location of the disaster is also affected. The total area of Japan is 370,000 km^2 Divided by the area affected, 8000 km^2, we get 46 localities. Assuming that disaster is a random phenomenon and that great disasters do not occur, these localities cannot all be affected simultaneously. If we consider one locality as one colony and we spread the population over the entire area, the danger from natural disaster is also divided. In this case, in one area even though the population is concentrated in big cities, the expected value of damage does not change greatly. The figure 46 is close to the number of prefectures and metropolitan councils, suggesting that the division was logical.

Today, with widespread industrialization and advances in transport facilities, a colony may tolerate size increase. Therefore, the suggestion to amalgamate various prefectures has received support. However, since this contradicts the concept of population disbursal, a compromise must be reached. An area should be divided into at least ten colonies. If each locality is at least partially self-sufficient, then if any one region suffers damage due to natural disasters and production is halted, neighboring regions will be able to continue supplies until the situation returns to normal.

The natural environment also influences population distribution. Tokyo's west side houses many upper class residential areas while on the east side factories predominate. While this development might be coincidental, wind direction may have influenced this pattern. Although the wind is partially controlled by the earth's surface, if we rise above 1000 m, smoke rising from chimneys can easily move eastward since western winds are more prevalent. Therefore, it is better to construct houses on the west side of the wind as in the case of the upper class residential blocks.

In constructing an industrial complex, a seaside site is advantageous for the transport of raw material. As the population expands, industrial complexes should expand in unpopulated areas with particular reference to climatic conditions.

Agricultural crops must be harvested at appropriate times and places since weather conditions affect crops so intimately. For example, paddy is mainly a tropical crop and is not usually cultivated in the northern region. With improved strains and cultivation techniques, rice can now be produced in the north and the Tohoku region is today becoming the rice bowl of Japan. However, in the northernmost part of Hokkaido, harvest is irregular due to an unfavorable climate. The efficacy of growing rice there must be examined.

THE OPTIMUM POPULATION FOR URBAN LIVING

Rapid urban growth is today a major problem in Japan.

Early man formed small groups and lived by hunting animals. Later he started to farm and with modern industrial developments his productive power has increased. The size of man's group increased to the village, town and urban center and in these he started to build his social life as he found living in a group more convenient. Creatures such as ants, bees, birds and monkeys also live in groups, but the nature of their society is obviously different.

There are some disadvantages if a group becomes excessively large. Modern Tokyo is a good example of this. Overcrowding has led to inadequacies in the water supply, transport facilities and so on and increasing pollution is a related problem. Again, in terms of disasters such as earthquakes or storms, the increasing size of social groups must be carefully considered. The great Kanto earthquake of 1923 clearly illustrates this. The size of a city should be determined by a balance between favorable factors such as the ease of life and such problems as the preservation of the city. Let us examine this problem with a simple model.

Shelter and roads are facilities which ease man's life, but the most important use of land is in agricultural production. In designing a city we must plan for agricultural land, pasture land, forests and so on to support the city and in addition facilities must be provided for the transport of food and other products to the cities. Here we assume that only the cities consume these commodities and that the area necessary for one man to live is a, including space required for housing and so on. We therefore assume that food is produced outside the cities and the amount of food required for one person is assumed to be produced from an area A. Now A also includes the area necessary for persons engaged in production and hence their population is not included. To transport the food produced to the cities, an effort proportional to the distance is required and Co people per person per unit distance are assumed to participate in this task.

According to the model shown in Fig. 29, the number of persons necessary for transportation becomes:

$$\int_{Ro}^{R} \frac{2\pi Co\,\rho^2\,d\rho}{A} = \frac{2}{3}\pi\frac{Co}{A}\,(R^3 - Ro^3)\,.$$

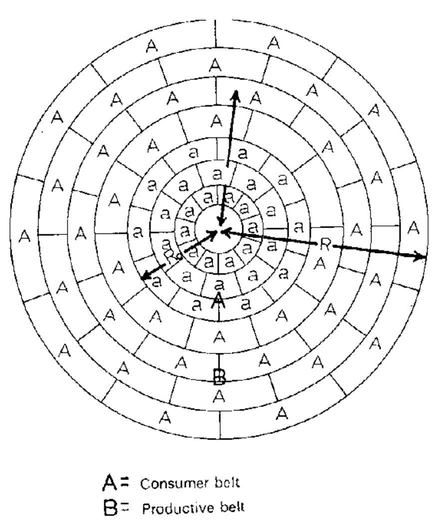


Fig. 29. An ideal city.

Here, transportation is the effort to carry things to the center of a city. The city population N can be determined from this as follows:

$$N = \frac{\pi Ro^2}{a} = \frac{\pi (R^2 - Ro^2)}{A} = \frac{2}{3} \pi \frac{Co}{A} (R^3 - Ro^3).$$

The first factor on the right side of this equation, R, is the population which can be supported by the food produced in the productive area and the second factor, Ro, is the population necessary to transport the food to cities. Generally, Ro is smaller than R and considering this, the approximate equation can be written as follows:

$$N = M\left(1 - \frac{2}{3} Co\sqrt{\frac{MA}{\pi}}\right).$$

In this equation, M is the population that can be supported on farm land. This equation suggests that in the beginning N increases with M, but at some point the increase is great and thereafter it begins to decrease. This maximum value of N is $\pi/3Co^2A$ and that of M is π/ACo^2.

This relation suggests that as the fertility of the land improves and A becomes smaller, the population of cities increases. If the efficiency of the transportation network improves, then the population increases proportionally to its square. We do not know the exact value of indices A or Co, but if we assume that A is 100 m^2 and if the distance over which the food for one person is carried is considered to be 200 km, then Co becomes its inverse. Using this value in the above equation, the population of cities comes to about four million.

This value is fairly realistic. The population of Tokyo in 1970 was 11.61 million, that of Osaka 2.98 million and of Ngoya 200,000. The population of New York is 11.49 million, London 7.7 million, Shanghai 6.9 million, Moscow 6.94 million, Bombay 5.7 million, Paris 8.2 million, and Peking 4.01 million people. The estimation of four million people is therefore not too far off.

There are similar findings in terms of the expansion of big cities. As the level of civilization rises, the population of big cities also tends to increase. As an example, let us look at the populations of Tokyo, Osaka and Kyoto (refer Table 29).

In these big cities, the population was almost constant through the Tokugawa period, about 1850, but since the Meiji period, during which western culture began to influence

Table 29. Population changes in urban areas
(in units of 10,000 people)

Year	Cities		
	Tokyo	Osaka	Kyoto
1750	100	40	38
1800	98	39	38
1850	120	33	37
1900	130	88	37
1930	497	245	95
1940	539	325	109
1950	678	196	110
1960	912	301	129
1970	1161	298	142

Japanese development and with increased productivity and transportation, the population has increased rapidly and is now from four to 11 times that of the Tokugawa period. The decrease in the Osaka population around 1950 was due to war damage and during the last 20 years the population has not changed as much as it has in Kyoto. By comparison we see that the population of Tokyo shows a continuous tendency to increase.

The main factor in this model is transportation. Transportation and communication are the links in human activities and they are the vehicles for the energy and material necessary for the maintenance of life. If we compare society to the human body, they are the nerves and blood vessels. As transportation and communication facilities improve, the population of cities also increases. As Elgrendel says, progress in transportation techniques can greatly expand the economic region. Increase in the speed of transport is shown in Fig. 30.

In fact, change in speed leads to many changes. Many factors are included in the definition of the speed of transport facilities--maximum speed, speed while transporting the material, normal speed, speed while carrying passengers and so on. Speed varies in different situations and depends on the place and type of transport used. Therefore, the optimum speed for city life cannot be so easily determined. Fig. 30 shows the maximum speed and the practical speed of transport facilities in different years. The increase in speed since the nineteenth century has greatly affected

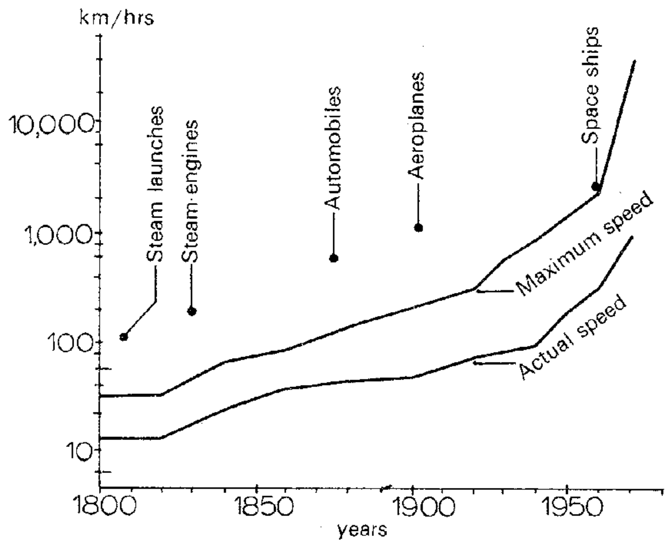


Fig. 30. Increase in the speed of transport vehicles.

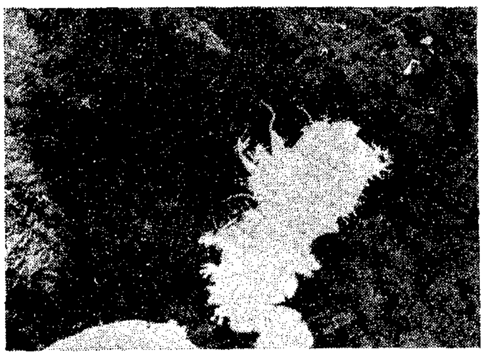
society. In earlier times, transport and communication were scarcely developed by today's standards and populations consequently were more stable. Exchange of ideas and information was also slow, resulting in the slow development of science and technology.

The early twentieth century witnessed the wide use of steamships and locomotives and with advances in electronics and wireless communication, the sphere of man's activities greatly expanded. Nations consolidated their territory and could control vast expanses. The airplane, radio and television have made it possible for man to witness and participate in events in the remotest part of the world. The instant broadcast of the news of the assassination of President Kennedy on November 22, 1963 and the detailed daily reports of the war in Vietnam are good examples of this. Aware of his shrinking world, man has looked to the United Nations as a forum of world politics and some leaders have begun to see current issues in a global perspective. While this is not due solely to advances in transport and communications, without them institutions like the United Nations could not have been formed.

As man forms a social structure and lives within it, roads are the arteries and communication facilities the nerves. National planning is then an effort to interconnect them.

Chapter Fifteen

Planning the Future



Satellite photograph of a part of southern Kanto (Courtesy: K. Sugita).

It is neither God nor Satan who created this world of ours, but it is man alone, a shining, example in the animal kingdom. This man-made world is not very comfortable to live in and yet we cannot leave it.

Natsume Soseki
Grass Pillow

THE SEVEN MAJOR PROBLEMS IN THE FUTURE OF JAPAN

Let us review the major problems of natural science likely to confront Japan in the future.

The first is the problem of population. Increasing population is the base of all other problems. No immediate solution presents itself, but the promotion of birth control should help to control population growth.

Related to population increase is the problem of space. Shortage of living space is manifested in rising land prices and is a source of severe frustration to salaried people. Solutions to this problem will come through economic use of land, population control and proper distribution of industrial areas. A rational national plan must be prepared and implemented.

Food is the third problem. The availability of food is essential for the survival of mankind, but even today Japan cannot supply her people from domestic sources. Rice production meets the demand, but other types of food have to be imported in large quantities.

The population explosion has created a food supply crisis in all nations, particularly in the advanced ones. As the climate of the world changes, it is feared that food shortages will increase. Fish, an important source of animal proteins, are decreasing because of increasing pollution and heavy catches. This worsens the food situation.

Fourth is the problem of resources. With some exceptions, Japan is not heavily endowed with natural resources. However, because of its geographic location, Japan can import raw materials from many countries. Their utilization in industry has resulted in astonishing economic progress. However, the world's resources are limited and many of them may be depleted within a few decades. To prevent this, the existing resources must be used more effectively, without wastage while new ones are developed. Part of postwar Japan's Americanization is its limitless power of consumption.

Energy is the next problem. If we could conserve energy, we could largely solve the problem of other industrial resources. However, oil is man's main energy source today and at the present rate of consumption, it will probably last for only another 30 years.

Dependence on oil today is so great that modern times can aptly be called the 'oil age.' If oil reserves are completely exhausted modern civilization will suffer a severe setback. A solution to the energy problem is a great challenge for the next generation.

Pollution, the next problem, inevitably results from the enormous increase in human activities. Although a very small country, Japan has risen to second place in economic growth among the nations of the free world. At the same time, Japan also claims first place in pollution, with all its related effects.

The last problem concerns change in the natural environment. Since human beings exist in nature, they are affected by change in the natural environment. The long term consequences of such changes are very significant. Today, when the climate of the world is also undergoing change, this matter must be considered seriously. Then, too, human activities adversely affect the natural environment.

Medical science has advanced rapidly in recent decades but critics warn that these advances may adversely affect future generations. Human life span has increased and incurable diseases can now be treated. But is this advantageous to the human race as a whole? In the past only the fittest survived. Today, the physically and mentally handicapped are increasing in number, placing a heavy burden on society. This problem, then, too, must be included in those facing future generations.

THE CUMULATIVE EFFECTS

Each of the problems we have outlined is important in itself in Japan's future but taken together they are even more serious.

Today's crises are the result of several interacting factors. But this is not so in the case of natural calamities. Let us consider fire disasters as an example. The basic factor in a fire is the flammability of the substance. The next most important factor is the fire fighting facilities. Both of these can be regulated by man so that even when an accident occurs, it can be controlled if man is prepared and vigilant. However, the third factor, atmospheric conditions, cannot be manipulated by man. If the weather is dry with strong winds, a fire will spread easily. The combination of these factors affects the seriousness of the calamity.

Analysts today gloomily forecast Japan's future. Despite the decreasing growth rate, the population is still increasing and by 2000 A.D. it may reach 130 million. This is 25% more than the present population and to feed so many people at least 25% more food and other resources will be necessary.

Today, in addition to large quantities of food, many other materials are imported and these demands will increase in coming decades. Indigenous production of food and other materials has almost reached its limit. Climatic factors are already unfavorable and by 2000 A.D. may be worse. This unfavorably affects food production. Food shortage is already a global phenomenon and if it worsens even present imports cannot be assured. Pollution from the use of agrochemicals is spreading and some experts urge the curtailment of their use. That, however, will hamper increased agricultural production.

Dire predictions suggest that oil resources will be exhausted within 30 years. If oil is depleted, automobiles cannot be used and air and sea transport will be curtailed. The electricity situation will also deteriorate. Attempts will be made to use coal and atomic power along with efforts to use coal with oil, to synthesize new fuel from atomic power, to harness solar energy and so on. Prohibitive costs, however, will inhibit the widespread use of some of these alternative sources resulting in curtailed consumption.

Transportation of goods will also be hampered. Even today Japan has to import large amounts of food and other materials. On a global level, since the food producing regions and those with natural resources are often remote from the principal consumers, disruption in transportation will only foster shortages. These deprivations and resulting tensions will lead to war and regional disputes. Since arms and ammunition today are so highly developed and readily available, the spoils of war may be simply food and other resources captured by force.

THE LOOMING CATASTROPHE

The forecast for the rest of this century is indeed dark. While countermeasures may be able to limit the effect of the evident problems, we acknowledge that mankind faces a very difficult moment.

The human race aspires toward a better life and seeks more and better material comforts. Mankind's productive activities have assumed enormous proportions. The looming catastrophe may be the consequence of these activities. The natural world, including man, exists in an ecological balance. If some part of this system is disturbed, the effect is felt everywhere. Only recently has it been possible to identify and manipulate the problem to man's advantage. The material resources which have helped to build modern civilization are now depleted and cannot be replaced.

Organic resources which use solar energy form a closed system in natural ecology and reproduction is possible. Since the United Nations Conference on the Human Environment held in 1972 in Stockholm, the management and preservation of natural resources has been seriously considered.

Mankind's productive activities before the time of Christ were insignificant and in tune with the natural environment. If we were able to return to these conditions, our problems of vanishing resources, pollution and so on would be solved. While this is hardly possible, let us examine the question in terms of energy. If we can return to even the conditions of the early Showa period, using hydroelectric power, charcoal and other energy resources efficiently, we can meet the demands of the present population. Using the requirement level of the Showa period for metal resources too, consumption could be reduced to one-tenth the present quantity, thus extending the life of these resources. Pollution would cease to be a problem because of the purifying power of nature. But the food problem would still remain the most difficult one and should be a major theme of future research. Today obese children are seen in many parts of the country indicating that correct eating habits need to be inculcated. Food habits must be modified on a wide scale. Food can be produced from wood as well as grass and proteins can be developed from petroleum. Chlorella can be eaten with these products and can be used as feed for livestock and domestic pets, after which their meat can be consumed.

Man has overcome difficult situations in the past and with proper countermeasures could overcome this crisis also. Effective policies must be planned now to meet the major difficulties of the next 20 to 30 years. Social patterns and customs do not change quickly and if we force change people suffer in the resulting chaos. But we must begin to implement our new plans before conditions change drastically. From today on, we must envision the problems of the future, study the means of solving them and gradually absorb the countermeasures into our daily life.

MONITORING THE SOCIAL AND NATURAL ENVIRONMENTS

Both social and natural environments must be monitored as a first step in preparing for the serious problems ahead.

Society is indeed bound by laws and regulations but our concept of monitoring society is different. The distribution and density of the present population, the geographic location of industries and their productivity, the housing conditions of the people and so on must all be carefully studied. When all the data have been collected, countermeasures can be framed.

Similar steps should be taken to monitor the natural environment. When the earth's resources were unlimited, it was easy to adjust to nature and to live within it. Today, however, human activities are destroying nature which in turn is affecting human life. By monitoring the natural environment we will be able to foresee threats to human life and take necessary, if drastic, preventive measures. At no time in the history of mankind has observation of the natural environment been as important as it is today.

It is the responsibility of geophysicists to monitor the condition of the earth and to discern changing patterns. If they foresee a crisis, they must inform the authorities in advance just as the weather bureau posts storm warnings in a system that has proved very effective.

In our shrinking geopolitical globe we cannot confine our monitoring network simply to Japan. The whole world should be our objective. The atmosphere encircles the entire earth and its importance has been recognized by meteorologists for the last ten years. The meteorological departments of different countries belong to the World Meteorological Agency where plans are made to monitor the world atmosphere. The monitoring methods are being standardized, data exchanged, a communication network for weather established and a new plan is gradually evolving.

One of these projects is the launching of five stationary statellites over the equator to provide a 24-hour weather monitor all over the world. Of these five, the USA has contributed two, Europe and the USSR one each and Japan is expected to contribute one. The Japanese weather bureau plans to launch a satellite at 140°E.

A man-made satellite, depending on its internal construction, can also be used to detect pollution. The United States has already launched a satellite to search for natural resources. Such satellites are equipped with cameras which can analyze light of different wave lengths and assess conditions accordingly. For example, with infrared waves of 0.6 micron wave length, radiation from healthy plants is about 1.6 times greater than from diseased plants. Thus, the condition of the plant can be discerned from the amount of radiation.

Oil pollution can also be determined in a similar way by using ultraviolet rays.

However, to monitor pollution we must chemically analyze the atmosphere, the oceans and the earth's surface periodically. The World Meteorological Agency planned to conduct a periodic chemical analysis of the atmosphere and many countries do this for ocean waters. Biologists study these data to determine the state of various living organisms. Most of this work is conducted privately; only at the prefectural level in Japan is it conducted as an organized effort. While this is a good first step, pollution control should be conducted in Japan at the national level and then at the world level.

Once monitoring systems have been established, objective and scientific analysis of the changes in social phenomena and the natural environment must be made. Observation is important, but data must be collected and analyzed. In order to outline future policy, we must be able to say 'according to the following laws ...' and then mention a specific rule, as we do with weather or economic predictions. Today we cannot do this.

In solving problems such as pollution, we have to contend with pressures from industry and the issue has become politically sensitive. However, in planning the future, we cannot allow political considerations to bias the decisions. This is why political leaders were not accepted as members of the Club of Rome.

Nonetheless, politics cannot be completely ignored in the solution of these problems. Once plans for the future have been made and it is time to execute them the political leadership must assume the responsibility for implementation, economic coordination and social education. While planning for the future, these dimensions must be considered but they need not interfere with the final decisions.

THE LIMITATIONS OF SCIENCE AND TECHNOLOGY

Recent developments in science and technology are truly astonishing. The dream of going to the moon has been realized. But perhaps we have become overconfident with false hopes about science. Science is not magic and cannot produce miracles. A basic principle must be discovered before there is any advance. In Japan we are always ready to accept new scientific explanations but we quickly forget the earlier discoveries. We should overcome this tendency.

Guidelines for the application of science should be formed according to the principles of spiritual culture. Nature is neutral: when an hydrogen bomb explodes, it kills everybody, good and bad. Nature allows human beings no special treatment. Forces such as the atomic bomb, developed from modern science and technology, are beyond the control of natural science. Reason and humanism must exercise control.

In modern society, many problems are purely scientific and technological in origin but their solutions require political and economic input.

A good example of this is the recent countermeasures for pollution. Let us consider the specifications for sulfur dioxide exhaust in the chimney smoke of thermoelectric generators; this substance is largely responsible for pollution of the atmosphere. Since sulfur dioxide is harmful, it should not be allowed to enter the atmosphere at all. However, unless we stop thermoelectric generation completely we cannot reduce the sulfur dioxide to zero. And if we do so, there will be shortages of electricity. One compromise solution is limiting the percentage of sulfur dioxide in the smoke to a level that is not harmful to living beings but still permits thermoelectric generation. This safety level should be determined in consultation with scholars and scientists. There is always some latitude in such cases but the final figure is usually decided by political and public opinion.

If when we build houses, the design is so perfect that the construction can withstand storms or earthquakes of any strength, the cost will be prohibitively high and the houses would not be convenient for daily use. On the other hand, if we reduce the strength of the building only to lower the cost of construction, even a weak storm or earthquake could topple it. The problem is thus one of selecting the proper design and this question has both economic and political ramifications.

NEED FOR A SPIRITUAL REVOLUTION

Technological improvements will remain imperfect and inefficient if the present crisis of civilization is not solved. Basic reorientation is necessary to build a brighter future. What do we desire from the affluent life? What are our objectives in living a more civilized life?

Affluence means high salaries and the smaller the proportion of expenditure on food (the Engel coefficient), the more wealth there is. The per capita level of energy consumption or steel consumption can be taken as indices of the level of civilization and the higher their values the more affluent the living. Table 30 shows these values for various countries of the world.

This table suggests that, with a few exceptions, these variables change in the same way and in the more developed nations all values are higher. Expenditures on housing, transportation and entertainment have a progressively large proportion as affluence increases. An affluent life then means a life with relatively higher entertainment and transportation costs.

But, can we define the affluent life only in this way?

Table 30. Per capita income for various countries

Country	Per capita income (1969) in 10,000 yen	Engel's coefficient (1955) in %	Energy consumption (1969) in kg coal	Steel consumption (1969) in kg	Population density (1970) people per km^2
USA	118	27	10774	540	22
Sweden	95	30	5768	545	18
West Germany	75	32	4850	473	114
Canada	72	22	8794	377	2
Australia	71	27	5200	389	2
France	66	-	3518	223	93
Norway	64	30	4430	279	12
UK	51	31	5139	368	228
Japan	46	47	2828	258	280
Austria	45	37	2995	236	89
Italy	41	46	2431	277	178
USSR	37	-	4199	344	11
Spain	24	-	1354	100	66
Mexico	15.2	-	1044	56	26
Chile	10.1	39	1210	76	13
UAR	6.3	-	221	16	33
Brazil	6.0	-	481	44	11
Philippines	5.6	-	261	20	128
South Korea	4.4	54	641	-	323
Thailand	3.8	-	197	13	70
India	2.8	-	193	16	168

With the advance of civilization, a more affluent life becomes possible. However, in the more developed nations, we find that although the average life span is increasing, the mentally handicapped, the criminal elements and the traffic casualties are also increasing. In modern society mental stress is increasing, causing depression and insecurity. President Kennedy of the United States, a highly developed nation, was assassinated while in Japan, Mishima Yukio committed suicide. Such incidents support the above argument.

In the past, when material things were less abundant, people believed that an affluent life meant a rich material existence. But today material wealth has overwhelmed us and we feel the need to bring spiritualism into our lives. For example, as pollution becomes more acute, we wonder which life is preferable: life in the cities where traffic chaos is a daily phenomenon or the less developed life of the village. Both have their merits and depending on one's habit, one or the other will be suitable. For the Japanese, life in unexplored parts of Africa would be extremely difficult, whereas for the Africans life in Tokyo would be impossible.

Looking back into history we imagine that people led simple life in terms of material benefits. But was that life really so deprived? The articles displayed at the Shosoin Temple certainly belie this. And spiritually the civilization was highly advanced.

From the ancient Egyptian civilization which flourished on the banks of the Nile we find this passage translated from hieroglyphics:

> "Become a record keeper, free from all sorts of manual labor. He who becomes so never uses the plow and never lifts a basket. It is not necessary to pull the oars and there are no memories of anguish. He does not have to serve many masters, nor are there many who are senior to him. One who does not take this advice must obey his seniors right from birth. In childhood they are valets of troops and as they grow older they become new recruits."

Human nature has changed little through the centuries. The ancients also aspired to the white collar class and despised laborers.

The crisis of modern civilization is simply that man has put all his efforts into developing a material civilization and as a result we have become predominantly a consumer civilization. We should now alter our concepts about the affluent life, reduce consumption and gradually move toward a more spiritual way of life. Only then can we avoid the dire consequences of today's crisis.

Postscript

Today the people of Japan, in fact, people around world, face very difficult times. There is an urgent need for us to forecast the future and to find ways to avert forthcoming disasters. These ideas occurred to me more than a decade ago. I began to collect the relevant data and, considering the related problems, decided to write about it in my own way. Now many more people have begun to take an interest in these questions.

Discussion of such a vast topic was indeed an ambitious undertaking for me alone. However, in today's complex world we cannot leave our destiny to specialists only. There are many ways to approach the topic I selected and while some may be more appropriate than others, it has been my experience that many predictions based on macroscopic considerations have been valid. On this basis I set out to compile the available data and publish them in the form of this book.

The subject is related to my own specialization and I hope I have done justice to it. I have arranged the book according to my own perspective with which the reader may disagree.

The subject is related to my own specialization and I hope I have done justice to it. I have arranged the book according to my own perspective with which the reader may disagree.
I apologize for any omissions and would appreciate the readers' criticisms and comments.

Each chapter was written independently. The reader may therefore skip the parts he finds repetitive. I have tried to reduce the number of mathematical expressions so as not to confuse the average reader. Nonetheless, I fear that there may be other difficulties for the reader. Some may feel that the inclusion of figures and charts makes the work complicated and yet we can hardly comprehend the subject without the support of statistical data. I have therefore inserted several figures, tables and charts. Although the numbers in the various tables have been carefully selected from the data I have collected, I cannot guarantee the accuracy of

each figure. I apologize also for omitting the honorific forms in the main text.

The chief editors, Mr. Koto Hiroshi and Mr. Nemoto Junyoshi, offered great assistance and good advice while publishing this book. Mr. Noto Masoa, Miss Kano Chieko and many others were very helpful in arranging the manuscript, proofreading and preparing the final copy. My friends in the Meteorological Bureau helped to collect the photographs published here. I would like to take this opportunity to express my heartfelt gratitude to all of them.

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