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Constraints on Development
—Focus on China and India—

MARCH 1999

The Asian Population and Development Association

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FOREWORD

The estimate of the world population in 2050 has been revised downward from 10 billion to 8.9 billion merely in the past six years. The projection was amended in 1998 and the correction has been announced recently by the United Nations. This denotes a 1.1 billion reduction of forecast, and can be regarded as remarkable progress on the part of the human species in its efforts to solve the population problem.

There is still however a critical element in the issue which must be seriously considered. This is the fact that the massive population of baby-boomers - born during the high birth-rate period -is now approaching marrying age. This means that a corresponding volume of population, which could be more than 80 million at its high, will be added annually over the next several decades.

Total fertility rates have declined so markedly that they are already below replacement level in not only most of the developed countries but even in some developing countries in Asia, including Singapore, China, Korea and Thailand.

Even the issue of population explosion, the species' greatest crisis, has begun to seem more hope. On the other hand, however, destabilizing factors of a global magnitude expand increasingly as if to cancel out that hope. These factors include the food problem, environmental deterioration, and the world political disorder.

One of our strategies has been to attempt to find a clue to the solution of such multiple global crises in Asia, especially in China and India, to get a grasp of the Asian situation. The global impact of a 1.2 billion of population in China and 1.0 billion in India, each of which are expected to rise to 1.5 billion to make a total of 3.0 billion, is not only a matter of population size itself. These nations' activities in terms of conversion to population replacement level and economic growth are considered as having a crucial influence on trends in Asia as well as in the rest of the world.

The fact that China, as a population giant, has developed a globally unprecedented system to control its birth-rate, and has achieved high economic growth by introducing the free market system into a socialist society, is a reality distinct from criticism of its methods. It should be focused on as an important discovery in Asia.

With its own characteristics and considerable differences from the Chinese approaches, India is also beginning to make new progress quietly. Although the country that took the initiative in controlling birth-rate is still much behind China in birth-rate reduction due to various political and social constraints, it has finally arrived at an accelerating stage of development. As if to support such progress, modernized industrialization has begun.

Our research is conducted along the threads mentioned above with the aim of analyzing the possibility of departing from the constraints against development and growth by focusing on Asia, especially China and India. We would be honored if our studies were able to indicate to readers any implications concerning Japan's role or possible contributions in the years to come.

I wish to express our sincere thanks to The Nippon Foundation (Ms. Ayako Sono,Chairperson) and the United Nations Population Fund (Dr. Nafis Sadik, Executive Director) for their most generous support given to our preparation of this document.

March, 1999

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Introduction

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Asia the Key to the 21st Century

Mankind Gone "Beyond"[1] "Limits to Growth"[2]

"Limits to Growth" (1972), a report for a Club of Rome project launched against the background of the unprecedented population expansion of the 1960s, warned of the demise of the human race that would be brought by continuous population growth and economic development. Despite the increase in population, the world resting resting on its laurels with the achievement of an affluent standard of living reacted against the alarm with surprised cries of "No way," or "That's too exaggerated."

However, "The Limits to Growth" constituted an important milestone in attracting serious public concern to the explosive increase of population. The theory of population growth control has fought its way through many complications mainly thanks to the ceaseless efforts made by the United Nations, and has registered some advances.

The (world) birth-rate, which determines population growth, has declined remarkably. Already 51 countries (with a combined population accounting for 44% of the world total) have reduced their total fertility rates, which measure the magnitude of population reproduction, to a point below the replacement level, and the number of such countries will amount to 88 in 2015, when, it is estimated, they will account for two thirds of the world population. Attention must be given to the fact that almost all the developed countries have attained the replacement level of population, which denotes two or less children per mother, and some developing countries including Korea, China, Singapore, and Thailand have also reached these low birth-rate levels. Therefore, assuming that control of population growth will be further reinforced, it may be considered that the world is beginning to succeed in solving the problem of population expansion warned of by the Club of Rome in 1972.

"Beyond the Limits: Confronting Global Collapse, Envisioning a

Sustainable Future" published in 1992, 20 years after "Limits to Growth", pointed out that although the species was already in the process of going beyond the limits to growth, there were some new developments, on the other hand, which implied availability of solutions. "The speed at which mankind consumes indispensable natural resources and produces contaminants has already exceeded the physically sustainable speed in many cases."[3] However, the authors maintain a hope that intellect and creativity on the part of human beings who deeply regret such behavior will lead to the attempt to make significant improvements.

Increasing Inscrutability and Anxiety

Progress of worldwide efforts to cope with the population explosion has ironically been complicated by fears of global environmental deterioration, of floods, draughts, abnormal weather, global warming, etc. associated with the increased sophistication and geographical expansion of human activities. Such global upheavals have become even more critical because of the disorder of the world politics resulting from the end of the cold war.

The food problem represents these multiple crises. The drastic advance of modernization, industrialization, and urbanization have caused rapid reduction of land area including land needed for food production, shortage of water resources, and degradation of soils. With no more room left for improvement of agricultural productivity, the high point having been attained soon after the Second World War, the capacity of the world's food supply to feed the ever increasing population has become an urgent issue.

More than one billion people are said to be suffering from starvation in the world. The world population exceeded five billion in 1987, and will likely reach 6 billion in 1999. This will represent an increase of as much as one billion in a mere 12 years. Without any further improvement in food productivity, an additional one billion are expected to face starvation.

There is both pessimism and optimism about the possibility of increase in food production. The pessimistic views are represented by the studies of

Lester Brown[4], who has become internationally well known. With detailed positive analyses, this study verified the inevitability of food shortages. For example, it compared demand for and supply of grains in 1950 and 1990, and made forecasts of those in 2030. According to its forecasts, China will produce 263 million tons of grains and consume 479 million tons, creating a 216 million tons shortage. Likewise, India will have a 45 million tons shortage in 2030. The shortage expected in China is said to exceed the current total grain exports of the world.[5] Brown did, of course, suggest several measures for avoiding the possible catastrophe, as well as warning of the food crisis. One of his suggestions is the stabilization of the population as soon as possible, quite a natural, but notable idea.

Conversely, there are a number of optimistic views as well. A. H. Toffler[6] is one such optimist, and is as well known as Brown in Japan. He takes a bright view of the future, maintaining that the current status is no worse than in the past, that India shows a potential for increased food production based on advanced bio-technology. He has demonstrated that although India's grain production reached 93 million tons in the 1960s and was thought to have hit the ceiling, the country is now producing 191 million tons of grains, and feeding an additional population of several hundred million population on top of the 1960s population of 500 million. His view is an optimistic one resting on strong expectations and hopes.

As has been seen, both views are more or less biased arguments, and it is impossible to prove that one or the other is correct. John Bongaarts once said that it was desirable to be both moderately optimistic and pessimistic, without taking either too optimistic or too pessimistic views. The prospects for the 21st century are, however, becoming increasingly obscure.

The Next 50 Years

While obfuscating factors only increase with regard to the future, this does not mean that we cannot paint any picture of tomorrow. There is a hope in the population issue. The 1992 projection of the 2050 world population was 10 billion, but the United Nations adjusted the figure down to 8.9 billion six years later, i.e., in the projections issued in 1998. The decline of the birth-rate, an important factor in the downward correction, is expected to reduce the subsidiary population vital index substantially in the first half of the 21st century, ease the pressure from the crisis, and enable desirable measures to be undertaken.

However, we must note that the high birth-rate of the past will lead to a drastic rise in the young population, which could activate development if employment opportunities are successfully increased, but could cause social disorder if not. The past high birth-rate will also bring fast aging of the population. It is estimated that the proportion of the population of 65 years of age and over to the world population will reach 7% in 2000 and 15.1% in 2050 (the latter is the current level in Japan). Furthermore, although a decrease in population growth rate is expected, the first half of the 21st century will continue to see an immense annual increase in the population, which requires particularly grave consideration.

The world population is nearly at six billion now. The Asian population is approaching 3.7 billion, accounting for more than 60% of world population. Among the Asian nations, China and India, the world's two most populous nations, need to be given special attention. The Chinese population is forecast to reach 1 billion 276 million in the year 2,000, and the Indian 1 billion 6.8 million, making a giant population of 2 billion 280 million. These two countries hold a total population which is more than three times that of Europe. In other words, the Asian population is nearly 61% of the world population, and the Chinese and Indian populations together account for 62% of the Asian population.

In terms of the scale of population, Asia can be considered as representing the world while China and India represent Asia, and the presence of these areas has an even more important implication in that their populations' activities reflect those of the regions they belong to, and can affect other regions as well.

Asia has, indeed, played the leading role in the world in the field of population policy, especially in birth-rate control by means of family planning. The first Asian Population Congress, held in 1963, overcame the taboo of population control theory that operated on the stage of the United Nations, and India took the leadership here. Needless to say, the entire Asian consensus has made a great contribution to combined world activities.

Japan was the first country to attain the conversion to population replacement level in Asia, and with a slight time lag, this achievement was rapidly duplicated in the East and Southeast Asian countries. Total fertility rates in the all East Asian countries, except for Mongolia, have reached levels below replacement level. The index for the whole of East Asia also is below the replacement level, at 1.88. Such a drastic decline in the birth-rate had not been expected. Among Southeast Asian countries, Singapore and Thailand have also attained birth-rates below replacement level. Other countries in the region and in other regions as well have mirrored the trend.

In South and Middle Asia, where India is located, only Sri Lanka has achieved a decline in the birth-rate low enough to be very close to the replacement level. India, the giant of the region, yet maintains a total fertility rate as high as 3.39. However, this figure denotes a notable achievement, as the rate was 5.4 between 1970 and 1975, so that the average number of births per mother has decreased by two in the past twenty years. India is the country that took the initiative in adopting family planning as government policy after the Second World War. The popularization of family planning has never been easy amid the various constraints represented by different religions, the decentralization of power, a diversity of languages, and the caste system. Prosecution of the policy at certain parts of the bottom level of the country's administration was so extreme that political disorder was created, miring the implementation of family planning. This, in turn, slowed down reduction in the birth-rate in India.

However, it is certain that the steady decline of birth-rates in recent years will continue further. According to the National Family Health Survey

(NFHS) of India for 1992 and 1993, the average number of children desired by married females from the ages of 13 to 49 is still as high as 2.9[7]. On the other hand, signs of development in the Indian economy - especially economic growth in the advanced regions in the southern area - is expected to promote reduction of birth-rate.

The decrease in birth-rate in China, the world's most populous nation, has been so remarkable that the success has even provoked suspicion. The People's Republic of China after the 1949 Liberation was a socialist state where socialistic ideas impeded the spread of family planning. Notwithstanding, the Government, being aware of the serious possible impact of the population expansion on its food supply and economic growth, promoted the "Two Children" policy, and in 1979 finally introduced an "Only Child" policy that astonished the world. Through thorough administrative directives, persuasion of the people by advertisement and by education, and the people's consensus, the country's efforts to reduce the birth-rate has been a great success. The total fertility rate has fallen below the replacement level recently, reaching 1.92 (ref. 1990-1995, United Nations).Economic growth has maintained a level of about 10% in recent years.

It is estimated that the Chinese population will reach 1,516 million in 2050, and that that of India will exceed the former to amount to 1,532 million in the same year. The behavior of the two population giants, with different religions, races, and cultures, and with a total population of 3,050 million, is expected to have significant knock-on effect in the world as well as in Asia

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1. Changes in the Situation of Water Resource

According to measurements by the United Nations, the total water resources for the world population, i.e., the total river flow obtained by subtracting evaporated and absorbed water from rainfall, is 43 trillion cubic meters, or 7,000 m^3 per capita. The resource has been maintained at a stable level for a long period, apart from some aberrations caused by the recent changes in the global environment.

Of the resource, the river flows relatively easily available to the population is 9 trillion m^3 plus 3.5 trillion m^3 of storage in dams, etc., making 12.5 trillion m^3. However, it is said that only about half of this figure is actually used. Further, taking into consideration the increase in world population, the per-capita available amount has declined by 40% in the quarter of a century between 1970 and 1995. Of course the 40% drop is not an actual decrease in the used water amount and does not exactly reflect the volume of water shortage, since the loss is more or less recouped by more efficient use. I would also point out that 50% of the resource is, globally, left still unused.

Another critical feature of water as a resource is its unevenly distributed locations. There is only 2% of the resource in the arid regions that occupy 40% of the land area of the Earth. Such regional difference in availability of water have diverse consequences, and the effective utilization of water resource has historically depended on human development and the level of civilization in the region.

Such uneven regional distribution of water resource and population generate the reality that in Asia the total volume of river flow is greatest in the world while that per capita is the smallest. As the monsoon zone, Asia is blessed with sufficient rainfall, but per-capita rainfall is substantially below the world average of 26,871m^3; for example, 5,907m^3 in China, 5,160m^3 in Japan and 5,061m^3 in India. On the other hand, 13,985m^3 in Thailand and

12,738m^3 in Philippines denote affluent rainfall, but do not necessarily mean more effective use of water than in the three former nations.

In recent years, serious problems have affected water resource which have long been more or less stably maintained. The cause is the changes in the global environment.

Following industrialization and urbanization associated with population growth, energy consumption has increased, causing greater emission of CO_2 , a major factor in the greenhouse effect, and raising the atmospheric temperature. The extent of the symptoms and the prognosis may not be precisely obtained for the moment, but the direction of these changes is obvious. It is reflected in the decreases in rainfalls, river flows and subsurface water, and saltwater intrusion into subsurface water, as well as in the decline in the residual rate of water resource caused by increasing demand due to the rising air temperature.

These quantitative changes in water resource may be regarded as smaller in effect than the impact of population growth. However, facing further growth of population (estimated at 5 billion for the next half century), the UN Sustainable Development Committee has raised the issue of, "Water resource as one of the greatest problems for the 21st century; i.e. global shortage of water." Furthermore, in 1992, the International Conference on Water and the Environment (ICWE) issued "The Dublin Declaration on Water and Sustainable Development". In 1994, United Nations General Assembly named March 22nd as "UN Water Day", thus beginning to draw people's attention to the forthcoming crisis in water resources.

Although reactions to the water crisis differ between industrialized nations and developing nations depending on regional changes in population and environment, both of them share a common sense of crisis.

2. Industrialization and Water Resource

The age of stable food supply through settled agriculture is said to have lasted for some 10,000 years, while the population has grown from some 5 million to 500 million. It was, however, industrialization starting in the 17th century that led population growth to the present drastic level, multiplying the number by ten times in a mere few several hundred years. The rate of growth is even accelerating, and the world population, as forecast by the United Nations, will likely reach 10 billion in the mid 21st century, up from 6 billion in the late 20th century.

Needless to say, the development of agriculture, with its increased capability to feed the species, has supported this population growth. Nonetheless, as mentioned in the later chapters, industrialization is beginning to have an influence on water resources, although not to the extent that agriculture does. The question as to the way for sustainable industrial growth, therefore, has been raised. Let us view the impact industrialization has on water resource in the following section.

The East Asia-Pacific region, which had been logging behind world industrialization, started to achieve rapid economic growth on the basis of industrialization in the latter half 20th century as the countries were freed from the bonds of colonization. The conversion of ratio of agriculture to non-agriculture (i.e., the rate of output to the national economy from the manufacturing sector exceeding that from agriculture) was seen in Korea in the 1970s, and then in Thailand, the Philippines, Malaysia and Indonesia in the 1980s, despite the time loss during the transition of policies from production of substitutes for imported goods in the 1960s to promotion of exports in the 1970s. China, after a delay in starting, is no longer an exception.

The influence of such industrialization on water resource has also been remarkable. The manufacturing sector's share of water consumption (1995) was 23% in the leading area, Europe, being a third that of agriculture, but was still only 9% in the whole of Asia. However, regional differences are observable depending on the progress of industrialization, 33% in Japan, and 16% in Korea. To consider the impact of industrialization on water resources, the issue expected to continue to be important, let us now review time-series relationships between changes in industrialization, changes in structure of water resource consumption, and manufacturing sector's share of water consumption.

In the past 30 years in Japan, where the service industry's prosperity reflects the falling growth of the manufacturing sector's share, the water consumption of the latter sector has dropped slightly from 18.7% to 17.0%. In Korea with its early industrialization after Japan, the manufacturing sector's share has grown 20% while its share of water consumption doubled has from 4.3% to 9.4% over the past 20 years. The industrial share of water consumption has also doubled in Indonesia as one part of the target of the nation's economic plan, due to the rapid industrialization (the level has doubled in the past 30 years). The differential increases in industrial water consumption against the growth of output reflect different levels of industrial development, so we need to take into account the different components of demand for industrial water.

"Industrial water" is defined by the Water Resources White Paper of the Japanese government, as including a variety of uses such as for boilers, raw materials, product processing, cleaning, temperature adjustment, etc. The greatest consumers are the chemical industry, the steel industry, and the paper and pulp industry. In Japan, basic material type industries, including these three, together account for 84% of the total consumption.

Such industrial dependence on water resource is common to other countries as well, and the level of progress in industrialization is seen in the trend of the share of industrial consumption of water resources, as mentioned above. It should be noted that the flattened industrial consumption of water of Japan in recent years is due to the advanced resource saving measures.

These include high recycling rate of water; 80 – 90%, in the industries consuming the greatest amounts; and the high level of seawater use; 20 – 25%.

It is desirable that such resource-saving experiences where be applied in measures as regards water resources in China, where industrialization has speeded up recently, the industrial share of water consumption in Asia exceeds that in Japan.

As has been observed, industrial water consumption has relatively low elasticity in relation to increases in industrial output, and composition of the water consumption by sector has gone through a stable transition in recent years in Japan. Special efforts have been made to achieve this favorable trend, which I wish to detail. As far as the public water supply is concerned, the proportional cost of industrial water consumption per output is far below that of households' water consumption. This is true even in the industries which are great water users. In contrast with the much lower efficiency in agricultural water consumption, which depends on natural water flows, notable further measures have been taken with regard to industrial water consumption. Recycling rates of the latter in Japan have been rising consistently since 1975. The ratio to the whole industrial water consumption exceeded 70% in 1977, and reached 77% in 1995, albeit with some variations between individual manufacturing sectors. Thanks to such water-saving measures, the amount of supplemental fresh-water used has tended to decrease on a long-term basis since 1975.

The factors contributing to the increase in the recycling rate are said to be (1) Constraints from tighter regulation on use of groundwater, (2) Consideration of draught water flow, (3) Effluent regulation, and so on. It should be appreciated that all measures taken to deal with these conditions have been in accordance with the basic strategy of efficient use of water resource, and made use of features of industrial technology.

In developing countries, the concept of "unit requirement" of water has not prevailed due to the relatively low cost of water. Examples can be raised from those great water consumers, the pulp and paper industries in Japan and China. Water consumption per ton of pulp in Japan (1989) is 120 tons whereas that in China is 400 tons – more than threefold the former. Even in Japan the figure was as great as 270 tons in 1970, so it can be observed that the past 20 years of efforts have attained such remarkable result. While industrialization in developing countries is naturally expected to further accelerate, the need of support for and transfer of water saving technology will increase.

3. Urbanization and Water Resource

In ancient history, cities may have evolved as bases for trading. However, real urbanization (as measured by the rate of urban population growth) made progress only after the transition to the modern industrialized society. There has been a marked increase in the world urbanization rate, which was 30% in 1975, 40% in 1980, and 45.3% in 1995.

Whilst industrial locations vary depending on the nature of industries, e.g. raw material-oriented or consumer-oriented, etc., urbanization and industrialization have synergetic effects on each other, being so to speak two sides of the same coin. Industrialization, as an economic phenomenon and urbanization as a social phenomenon are closely related.

This logic should explain the reason why the speed of urbanization in Asia was behind that in Western Europe. Urbanization in Asia has, however, speeded up increasingly since the 1970s, as shown in the attached tables, proceeding hand in hand with full-scale industrialization. The urbanization forecasts for the year 2000 by country are (apart from 100% in Singapore and Hong Kong) 87% in Japan, 79% in Korea, 30 to 50 % in ASEAN countries, and 36% even in China.

Reflecting such progress in urbanization, the ratio of daily-life water consumption to total consumption in Asia was 6% in 1990, quite close to the world average of 8%. To give a few examples, the ratios are 17% in Japan, 11% in Korea, 6% in China, and 3% in India.

The time-series rates of daily-life water consumption in Asia have not always been precisely obtainable. But let us take the case of Japan as an example. While its urbanization rate has risen by 6 percentile points from 71.2% to 77.0%, the rate of daily-life water consumption has tended to increase slowly. The total consumption of daily-life water has certainly increased by 50% during the period, whereas the increase in consumption per capita per day is 25%, which is only a 1% edge-up per year. Such saturation of water consumption, maintained by a certain level of supply, may be one of the factors that keep the rate of daily-life water consumption from rising very much.

Associated with the population growth in urban areas, however, water consumption has been increasing markedly toward the 21st century. According to forecasts of World Resource Research Center, urban water consumption in China, one of the two population giants in Asia, will likely to increase by 120% during the period from 1988 to 2000. That in India, the other giant, will increase by 40% between 1990 and 2000, and by a further 50 percentile points by 2025 – a slightly slower increase than the former.

According to research by the United Nations, in developing countries, the proportion of population receiving sufficient water supply is 87% in urban area and only 33% in rural areas. This implies that urbanization is not hindered by the requirements of urban water supply.

Such situation related to urbanization suggests that there way be some effects of urbanization other than the lifting of the population's living or consumption standards, and the rise in the proportion of urban consumption of water resource.

Daily-life water, as a counterpart to agricultural water or industrial water, includes water for domestic use (drinks, cooking, washing, etc.) and, in a larger sense, water for urban activities. The latter includes water for commercial use, such as restaurants or hotels, water for public use, such as public toilets, and water for extinguishing fires. These kinds of water for urban activities form part of the infrastructure of the city, and are the investment needed when urbanization proceeds. So it must be emphasized that these are some aspects of the increase in demand in daily-life water consumption associated with the recent urbanization in developing countries.

Attention should be drawn to the following facts. Establishment of urban infrastructure stimulates the synergy effects between industrialization and urbanization. The increased demand for water, then, promotes research developments for secure urban water supply including daily-life water and industrial water, affecting suburban agricultural areas, and, in extreme cases, reducing agricultural land-area as has been seen in South East Asia.

In considering the relationship between urbanization and demand for water, an important factor to note is the scale of the city. In the development of a city, various factors, including regional attributes such as manufacturing sites, distribution networks, transportation, etc. re involved. While each city seeks its optimal scale, differences in scale between cities occur. Despite the differences, the obvious trend is that scales of cities are becoming huge due to the synergetic effect of industrialization and urbanization in recent years. In such huge expansions, the way cities secure water supply is changing the way they depend on water resources; viz, from dependence on natural water flows to the exploitation of water resource. Thus, large cities' measures to secure water resources, including the construction of dams, are more effectively planned, and are considered to have advantages, from the point of view of the amount of water secured, over the efforts of dispersed small and medium cities. Given such conditions, it is unlikely that urbanization is hampered by any reason related to water resource.

However, this does not mean that the progress in urbanization or greater city-scales will necessarily bring to the urban population advantageous water-resource conditions. As shown in the attached table, citizens' satisfaction as regards daily-life water tends to be lower as the size of the city grows.

Although the 64.6% satisfaction in Tokyo is relatively high, it is much below the 92.5% of towns and villages. The dissatisfaction rate of the former, 30% is more than four times that of the latter, which is 6.9%. The reasons for satisfaction or dissatisfaction may vary, but it should not be ignored that the major factors concern quality of water.

It is generally pointed out that as water resource exploitation approaches its limit, quality of water, as well as the quality of potable water which involves hygiene aspects such as sterilization, is lowered. In addition, it should be noted that the lack of flexibility in response to water crises, as mentioned below, can cause problems in obtaining the required volume of water in a certain time frame. There is a suggestion that government's willingness to invest in water resource exploitation may be impeded by the substantially lower cost (0.6%) people incur for daily-life water compared to their overall spending as consumers

4. Water Crises and Countermeasures

Although water resources have been steadily maintained over the long run, per-capita water resources have decreased by 40% in the last half century due to population expansion. According to population growth forecasts, the decrease in per-capita water resource will accelerate further. If we take into consideration the regionally uneven distribution of water in addition to the global environmental changes in recent years, partial water crises will be inevitable even on the assumption that the rate of the current use of global water resource is still 50%. The United Nation's announcement mentioned earlier regarding the crisis is also based on the forecasts that the number of countries suffering shortage of water will increase to 80 from the current 31, viz., an increase by 40% to 2.8 billion people from 500,000.

What conditions cause water crisis? For quantitative depletion, the causes include draught water flow or depletion of ground water due to decrease in water storage, and deterioration of the function of water storage facilities through earthquake or sedimentation. For quantitative depletion, the causes include accident due to deterioration of water quality, or increased turbidity due to flood in the short run, and eutrophication or ground-water contamination in the long run.

Furthermore, with regard to the water supply system, damages to the transport function and processing are anticipated due to earthquakes, blackouts, or collapse of ground. These scenarios are predicted even in the countries which have already invested in water management and infrastructures, while such conditions will occur inevitably and frequently occur in the developing countries which have to keep the constructing their supply system to deal with changing demand for water.

From the point of view of water resource management, we must take seriously draught water flow in the downstream Yellow River (albeit over time-frame) in recent years, and the catastrophe caused by the huge flooding of the River Yangzi, etc. in China.

Under such circumstances even in the short run, possible effects on industrial output and economic growth stemming from the shortage of industrial water are not negligible, although the nature of the problems is different from that in the long-lasting crises related to agricultural water. Also to be pointed out, as affecting people's life, is the serious influence on the quality, rather than quantity, of the daily-life water. Whereas the relationship between water-supply crisis and food-supply crisis is direct and clear partly because of the position of the region, the milder changes associated with the water crisis in industrialization and urbanization are, in fact, much greater in scale in view of the effect on global environment.

As industrialization has enriched the economy, which has in turn enhanced its capability of feeding a growing population, the increase in population has had great impact on water resource to support industry. Urbanization together with industrialization has, then, caused changes in the global environment that have augmented energy consumption, affecting conditions for locations of water resources. Thus the cycle of crises has become the problem we must resolve.

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Table 1 World Rainfall

Nation	Population (10000)	Measurement (1000km^2)	Annual Precipitation (mm/year)	Total Amount of Annual Rainfalls (100 million m^3/year)	Per-Capita Total Amount of Annual Rainfalls (m^3/year e.a.)
Australia	1,597	7,687	460	35,360	221,416
Canada	2,561	9,976	522	52,075	203,337
New Zealand	325	269	2,010	5,407	166,366
Former USSR	28,014	22,402	502	112,458	40,144
Sweden	837	441	700	3,087	36,882
Indonesia	16,694	1,905	2,620	49,911	29,898
U.S.A.	24,160	9,373	760	71,235	29,485
World	**491,700**	**135,793**	**973**	**1,321,266**	**26,871**
Saudi Arabia	1,210	2,150	100	2,150	17,769
Thailand	5,209	513	1,420	7,285	13,985
Austria	757	84	1,191	1,000	13,216
Philippines	5,558	300	2,360	7,080	12,738
Former Yugoslavia	2,327	256	975	2,496	10,726
Switzerland	650	41	1,470	603	9,272
Iran	4,591	1,648	250	4,120	8,974
Spain	3,867	505	600	3,030	7,836
France	5,539	552	750	4,140	7,474
Roumania	2,317	238	700	1,666	7,190
China	107,222	9,597	660	63,340	5,907
Italy	5,722	301	1,000	3,010	5,260
Japan	**12,557**	**378**	**1,714**	**6,479**	**5,160**
India	76,614	3,288	1,170	38,470	5,021
U.K.	5,615	244	1,064	2,596	4,624
Former West Germany	6,105	249	803	1,999	3,275
Egypt	4,961	1,001	65	651	1,312
Kuwait	179	18	120	22	1,207

Note: 1. The annual precipitation for Japan is the average for the period from 1966 to 1995. The population is according to the 1995 National Census by the Bureau of Statistics Management and Coordination Agency.

2. The annual precipitation for the world and for other countries are based on the documents of the UN Water Conference held in 1977. The population and populations (Mean estimated values for 1986) and measurements are taken from the UN World Statistical Yearbook (1985/86)

Table 2 Water Consumption by Application (Japan)

	Agricultural Water	Industrial Water	Daily-life Water
1975	65.2	20.6	14.2
1980	65.6	18.5	15.9
1985	65.6	17.5	16.9
1990	64.4	17.4	18.2
1995	64.7	16.4	18.9

National Land Agency: "Water Resources in Japan" (1998)

Table 3 Industrialization in Asia

	Japan	Korea	China	Malaysia	Thailand	Philippines	Indonesia
1965	31	25	14	25	21	27	
1970	33	29		25	25	32	19
1975	32	32		31	23	32	26
1980	33	36		38	25	32	32
1985	31	40		37	27	33	33
1990	34	45	34	37	29	33	33

World Bank Annuals, Reference of Asian Development Bank

Table 4 Water-Cost Ratio to Output (%)

	1980	1985	1990	1995
Manufacturing	0.103	0.136	0.126	0.147
Pulp and Paper	0.204	0.168	0.234	0.287
Chemical	0.285	0.291	0.281	0.334
Steel	0.074	0.148	0.139	0.177

Water Resource White Paper (1998)

Table 5 Industrialization

	East Asia	South East Asia
1950	16.7	14.7
1960	24.5	17.4
1970	28.2	20.0
1980	32.6	23.1
1990	34.2	28.1
1995	37.0	34.0

World Bank: Annual Report on Economic Development

Table 6 Satisfaction as regards Daily-life Water

	Total	Tokyo	Mid-sized cities	Towns and Villages
Satisfied	66.4	37.3	61.5	81.3
Content	17.4	27.3	18.9	11.2
Neutral	0.7	5.5	0.5	0.4
A little dissatisfied	10.1	19.1	12.2	4.7
Dissatisfied	5.4	10.9	6.8	2.2

(Reference) Prime Minister's Office: "Public Opinion Survey on People and Water" (1995)

Global Environment and Water Resources & Food Production

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1. Preface

According to recent studies of Earth Planet Science, the Earth having the radius of 6,380km, is said to have become the present size within 100 million years from 4.6 billion years ago. And lives were born in the primordial oceans about 4 billion years ago. Since then, the stream of lives has flown without ceasing, and evolved to the biosphere where various species inhabit as we see today.

The reason the lives have existed as long as for 4 billion years, despite the fact that extraordinary natural events, at times, caused massive extinction, should rest in the following basic conditions, that the Earth, where we live, has satisfied.

The temperature near its surface has kept between 0°C and 40°C, which is the suitable range for lives of organisms.

A substantial amount of liquid water has existed on the Earth, and protected the global environment from the harmful solar ultraviolet rays.

On the other hand, all the species on the Earth, including the human beings, obtain their energy for living from the solar energy stored in dry matters that are produced by photosynthesis of chlorophytes.

Photosynthesis of chlorophytes is closely related to the solar energy incidence, temperature conditions, and water resources. With the forthcoming explosion of the world population, securing energy for lives of human beings, viz., food production will be the greatest problem in the near future. To solve this problem, there is a constraint of limited land resources, as well as issues of securing fresh water resources and its efficient utilization.

This article will, therefore, briefly discuss the issue of global water resources from the viewpoint of global environment and food production.

2. Global Environment and Water

Recent valuation says that there is approximately water of 1.35 ~ 1.37 billion km^3 on the Earth, 97% of which fills seas (area of approx. 36.1 billion ha) with the average depth of 3,700m. This makes the Earth appear to be a deep blue planet of water, and so different from the other planets in the space.

So, the water should be the major factor that made the Earth a planet of lives, and has fostered the human race, the mysterious species. This chapter will briefly explain how the existence of water is related to the formation of global environment which allow lives in it.

1) Greenhouse Effect and Water Vapor in Atmosphere

By a simple balance equation of radiation energy, the temperature near the surface of the Earth without atmosphere, even with the current solar constant (= 1,367 W/m^2 = $1.96cal/(cm^2 \cdot min)$), can be obtained as follows (e.g., ref. Ogura 1997):

The temperature of the "naked" Earth: -18°C

In the meantime, by processing meteorological station's data that cover the surface of the Earth, the temperature near the surface of the Earth surrounded by atmosphere as it is now is as follows:

The temperature of the actual Earth: +15°C

From these two values, we can see that the current Earth surrounded by the thick atmosphere is kept 33°C warmer than the assumed "naked" Earth. This is due to the greenhouse effect of the earth's atmosphere. Therefore, lives are considerably owed to this effect that maintain the temperature condition near the ground suitable for organisms to inhabit. Although the greenhouse effect tends to be viewed with hostility today due to its relationship with the global warming, it stems from the worries that the human activities for production may lead the greenhouse effect faster than the pace that the natural ecosystems and human society can conform to.

As is well known, the earth atmosphere consists of diverse gasses, and its total mass is 5.3×10^{18}kg. Ninety percent of the air is in the troposphere under the height of 15km, above which is the stratosphere for the rest 10%. Of the total atmosphere, 99.9% is under the height of 50km making the atmospheric layer. The atmosphere is composed of roughly two types of gasses.

① Quasi-steady components: nitrogen, oxygen, argon, neon, etc.

② Greenhouse-effect components: water vapor, carbon dioxide, methane, ozone, etc.

The quasi-steady components account for almost 99% of the atmosphere, and their proportions are hardly affected by their positions, heights, or seasons. On the other hand, the greenhouse-effect components, also called variable components, substantially change their concentrations depending on the condition of the surface of the earth, levels of human activities, and seasons.

Both of steady components and greenhouse-effect gas components have a high transmissivity against the solar radiation incidenting on the Earth from the sun. The solar radiation energy, that has penetrated through the atmosphere, is absorbed by the surface of the Earth, converted to thermal energy, and after doing various jobs emitted as the infrared radiation, with its waves longer than that of the solar-radiation, into the atmosphere. The steady components have a high transmissivity against the infrared radiation as well. On the other hand, the greenhouse-effect gasses absorb infrared radiation quite well, and emit its energy as infrared-radiation energy which is proportional to their absolute temperature (= °C+273.15) to the 4th power.

Accordingly, where the greenhouse-effect gasses are included in the atmospheric layer on the earth, the infrared-radiation energy from those gasses are added to the incidenting solar-radiation energy, raising the temperature near the ground by the corresponding value. This is the greenhouse effect of the atmosphere. Table 1 shows how each of these gasses contributes to the atmospheric greenhouse-effect.

As shown in Table 1, approximately 33°C of the atmospheric greenhouse-effect is brought by the downward infrared-radiation energy (approx. 155W/m^2) coming from the greenhouse-effect gasses in the atmosphere. About two thirds of the energy is from water including as water vapor in the atmosphere, and only a third is owed to the carbon dioxide (CO_2) which is being the global issue. The difference between the impacts of the two types of gasses is more or less related to the difference in absorptivity in the infrared-radiation range, but major factors are the difference in abundance between the two, as follows.

Water Vapor in Atmosphere: 12,400 billion ton

Carbon Dioxide in Atmosphere: 2,628 billion ton

Therefore, water existing in atmosphere (i.e., water vapor) is the leading component for the atmospheric greenhouse-effect that plays a major role to maintain the temperature within the suitable range (0 to 40 °C) for lives near the surface of the earth.

Nonetheless, neither increase nor decrease of water vapor in the atmosphere is the issue for the present global warming. This is because the amount of water vapor in the air is a function of the air temperature, and so determined as a result of a change in the temperature. On the other hand, the concentration of carbon dioxide keeps rising along with the massive consumption of fossil fuels by human beings, directly enhances the atmospheric greenhouse-effect, and raises the air temperature. This is why it draws the attention from all over the world.

2) Function of Water to Relax Climatic Conditions

Water has considerably great specific heat and latent heat of vaporization, as shown below. Because of such characteristics, it takes relatively long to warm up or cool down water. When water changes its phase (liquid ↔vapor), huge heat energy is involved, where energy is actively transferred by formation, advection, or condensation of vapor,

Specific heat of water: $4{,}218 JK^{-1}kg^{-1} = 1.0 cal/(°C\cdot g)$

Latent heat of vaporization of water:

$$2.5 \times 10^6 Jkg^{-1} = 597cal/g \text{ (at 0°C)}$$

Such physical properties specific to water substantially relax global climatic conditions, which, in turn, form large areas with suitable climate for lives to inhabit on the Earth.

To describe the mechanism clearly, I will briefly explain the energy balance of the Earth as follows. Figure 1 shows the total annual energy balance of the Earth. Assuming the Earth's planetary albedo (= solar energy reflection coefficient) is 0.3, the planet earth and a unit area of the surface of the earth absorb solar energy per annum as follows:

absorption by the planet earth (Q_{sa}) = 179 kcal

absorption by the surface of the earth (Q_a) = 118 kcal

The difference, 61 kcal is the energy absorbed and scattered in the earth atmosphere. Not all the energy absorbed by the surface of the earth are used in the climatic phenomena near the ground. Part of it is emitted into the atmosphere as infrared radiation (I). By subtracting the radiation, I, the energy source of the climatic phenomena near the ground, viz., the net radiation (R_n) can be obtained. It is expressed as follows:

$$R_n = Q_a - I = 118 - 39 = 79 \text{ kcal} \quad (1)$$

This net radiation, 79 kcal is distributed as follows. Of the annual net radiation given to the surface of the earth, 83.5% is used to evaporate water from the surface of the watery planet, whereas 16.5% is used to transfer heat from the earth's surface warmed by the solar radiation to the cooler atmosphere.

Water evaporation (ℓE) = 66 kcal

Heat transfer into atmosphere (P) = 13 kcal

From these, the Bowen ratio, which characterizes the heat energy distribution on the surface of the earth, becomes as follows:

$$P/\ell E = 13/66 \fallingdotseq 0.19 \quad (2)$$

Therefore, the overall climatic conditions on the Earth can be regarded as moist (humid) and suitable for plant production, thus, inhabitation of lives.

The energy of 66 kcal used for evaporation of water from the surface of the earth becomes entirely sensible when the water vapor is condensed and precipitated in the atmosphere. The amount of water vapor (12.4 trillion ton) in the air, mentioned earlier, is maintained by evaporation of water on the Earth as well as condensation and precipitation in the air, and is at a dynamic equilibrium. This condensation heat (ℓr = 66 kcal), together with solar radiation energy absorbed in the earth atmosphere (61 kcal), the heat transport from the surface of the earth to atmosphere (13 kcal), is emitted as outgoing infrared radiation (I_s = 179 kcal) into the space.

While the situation of the Earth as a whole has been discussed so far, the earth is a sphere with a radius of 6,380 km, and the earth the quantities of incidenting solar energy, distribution of continents and that of seas greatly vary depending on latitude zones. As seen from the many observations, the weather of the earth is relaxed unexpectedly. This is because the global flows; general circulation of the atmosphere and that of the ocean are formed in the atmosphere and in the oceans and they transfer great amount of heat to the south and the north, as described in Figure 2.

Figure 2-a shows latitudinal variations of solar energy absorbed by the Earth and outgoing infrared radiation emitted by the Earth. In the zone between latitudes 35 degrees north and 35 degrees south, absorption of solar energy exceeds emission of infrared radiation. To the south and the north of this zone, on the contrary, the latter exceeds the former. Therefore, without the transfer of heat energy from the low latitude zone to the high latitude zone by general circulation of the atmosphere and the oceans, the temperature in the low latitude zone would become higher, and that in the high latitude zone lower as the time passes.

However, it has been observed that the respective temperatures of the low, middle, and high latitude zones are 25 to 30°C, 15 to 0°C, and 0 -15°C. This means that excess heat energy in the low latitude zone is transferred to the high latitude zone via the atmospheric and oceanic general circulation, supplementing shortage of energy shown in Figure 2-a. Figures 2-b and 2-c express transfer of sensible heat and latent heat in the atmosphere, whereas Figure 2-d indicates those in the oceans.

As shown in Figure 2, considerable heat is transferred towards north in the northern hemisphere, and towards south in the southern hemisphere by atmospheric flows and oceanic currents. Heat transport is more effective by the atmospheric flows than oceanic currents. This is because, in the atmosphere, heat is transferred by both the heat energy of air (sensible heat) and latent-heat energy of water vapor.

As we can see from the explanation above, the physical properties (large specific heat and evaporation-latent-heat) of water and its mobility equate the global thermal environment, and reduce the geographical variations. Through these functions, water contributes to form and to maintain the earth environment suitable for inhabitation of lines. This implies that water is not merely a resources but a factor to form the global environment. Therefore, water is the habitat itself for organisms.

3. Production of Plants/Foods and Water

1) Productivity of Natural Vegetation and Global Environment

Plant production is the fundamental basis of lives of all organisms on the Earth. This principle has been true for nearly 4 billion years of history of lives, and is considered to be true in future as well. This is why the chlorophytes, being the "plant producers", are called "**Green Atlas**" that quietly have supported and will continue to support all lives on the Earth.

The **Green Atlas** (Giant) receives the force to maintain all organisms from the solar radiation constantly supplied through the distance of 150 million kilometers in the space. The quantity of force is expressed as a net primary productivity (NPP, ton dry matter/(ha·year)) calculated from the following equation.

$$NPP = GPP - R \qquad \ldots(3)$$

where GPP and R are the gross net primary productivity of plants and its respiration losses, respectively.

Processing of data of a number of observations and model investigations of photosynthesis have led to the conclusion that a net primary productivity (NPP) of natural vegetation can be estimated by the following model (Uchijima and Seino, 1985).

$$NPP = [0.29\exp(-0.216RDI^2)]R_n \quad (4)$$

where RDI ($= R_n/\ell r$) is radiation dryness to express climatic dryness, in which R_n is net annual radiation (kcal), r is the total annual precipitation (cm) and ℓ is the latent heat of vaporization (kcal/gH_2O). The above equation implies that as RDI increases (drier), the efficiency of conversion from radiation energy to dry-matter production drastically decreases, and also that with the RDI value kept constant, the dry-matter production increases proportionally to the net radiation.

From Equation (4), where the climatic factors (RDI and R_n) are assumed to be variables, a model graph to express the NPP values and vegetation types can be created as Figure 3. As observed, the humid climatic zone with RDI<1.5 is covered by the forest zone from coniferous forests with low R_n values through tropical rain forests with high R_n values. In those areas, the net primary production increases from about 5 ton to some 25 – 30 ton/(ha·year). On the other hand, in the dry climatic zone with RDI>1.5, water supply drastically decreases, and so does the net primary production, with its vegetation type changing from forest-steppe, steppe, semi-desert to desert. The net primary production sharply drops to below 5 ton, and, in the area with RDI>3.0, down to below 1 ton/(ha·year), which is the biological border.

To estimate the plant production of whole continents of 14,898 million ha under the current climatic conditions, the geographical distribution of the net primary productivity of natural vegetation has been obtained, as shown in Figure 4. From the diagram, the NPP values vary in the wide range from under 1.0t/(ha·year) in the Arctic, tundra and horse-latitudes zones to 25 –

30t/(ha·year) in the tropical rain forests in the equatorial zone, reflecting combinations of thermal environments, water supplies, and solar radiation energy. Dot-meshed areas in the Figure 4 indicates high-production zone (10t and above). We can see that the high-production zone is relatively narrow compared to the vast lands on the Earth.

To quantify those, the area-frequency distribution curve with different NPP-values has been expressed in Table 2.

The areas of high production with its NPP of 10t/(ha·year) and above account for only 36.1% of the entire lands (14.889 billion ha). Especially, subtropical and tropical rain forests with the NPP of 25t(ha·year) occupy make only 3.5%. On the other hand, the biological borders with the NPP of 1t/(ha·year) or below are as much as 22.5%. This means that the real combinations of temperature resources, water resources, and solar energy resources on the Earth – in other words, geographical distribution of continents and oceans on the Earth – are not so favorable for plant production. How the expected global warming, caused by man, in the next century affects the results in Figure 4 and Table 2 is a crucial issue for not only the human beings but all the living things on the Earth.

From Figure 4 and Table 2, the maximum dry-matter production of ferrestrial vegetation under the present climate (the potential net primary production in ton/year) can be obtained. The results, the dry-matter production when taking into account human being's land utilization (actual net primary production), and the amount of plant production utilized by human beings are shown below (Uchijima, 1997):

Potential net primary production:	1,360	(100 million ton/year)
Actual net primary production:	816	
Yields of foods and timbers:	122	
Production needed for the yields of foods and timbers:	204	

Natural vegetation areas have been ceaselessly destroyed to exploit and construct farming, residential, industrial, and transportation lands. This tendency makes the actual net primary production as low as 60% the potential net primary production. Out of the former, human beings harvest and use 12.2 billion ton (15% of the actual net primary production). The last figure of the above is the value obtained assuming the harvest index (= yields/total crops) as follows.

Cultivated crops = 0.3, Timber production = 0.5

Grassland crops = 0.8.

With the harvest index employed, the amount of plants human beings harvest and use for themselves alone is as much as 25% of the actual net primary production.

As explained earlier, the amount of plants produced from vegetation is the base for lives of all organisms on the Earth. The above figures, therefore, imply that the species (i.e., the human beings) alone uses 25% of the net primary production of ferrestrial vegetation. In view that the world population will be almost 10 billion in the mid 21st century, even simple arithmetic clearly tells us that the human beings consumption will exceed 50% of the total plant production. Taking into consideration that natural vegetation, especially various forests, plays the roles below to support a number of wild lives, we can conclude that the human beings on-going monopolization of the plant production will lead to drastic decrease of wild species in a wide range in the near future. In other words, there is a risk that it will cause artificial massive extinction of species.

① Natural vegetation areas produce and supply many kinds of energies for lives.

② Natural vegetation areas are safe habitats for wild lives.

2) Plant/Food Production and Water Resources

As implied in Equation (4), the efficiency of conversion from solar energy to dry matters in plant production sharply decreases as the dryness of the climate that controls water supply to plants, i.e., radiation dryness, increases. This logic can be applied to crop production. As described in

Figure 5, the dry matter production of maize is approx. 12t/ha on sufficiently moisted field, and declines as the soil becomes drier. Where the soil layer has a 30% moisture, it is as low as approx. 3t/ha or a quarter of the former. This is because the formation of plants substantially deteriorates due to the decreased photosynthesis caused by shortage of water supply to the roots of the plants. Meanwhile, the harvest index (= yields/dry-matter production) is also halved from 0.6 to 0.3. Therefore, the yield of maize given by the equation below is only about 1t/ha which is far below about 7t/ha under the condition of sufficient soil moisture. This result denotes how crucial is securing water resources for crop production.

$$\text{Yields of Maize} = [\text{Harvest index}] \times [\text{Dry-Matter Production}]$$

Based on researches conducted to date, the water use efficiency (WUE) of dry-matter production of crop community of fields is expressed as follows. (e.g., Loomis and Conner, 1993).

$$\left.\begin{aligned} \text{WUE} &= \frac{\text{Dry Matter Production}}{\text{Amount of Evapotranspiration}} \\ \text{Transpiration Efficiency} &= \frac{\text{Total Dry Matter Production}}{\text{Amount of Transpiration}} \end{aligned}\right\} \quad (5)$$

The relationship between the two is as follows:

$$\text{WUE} = \text{Transpiration Efficiency} \times \left[1 - \frac{\text{Land-surface Evaporation}}{\text{Amount of Evapotranspiration}} \right] \quad (6)$$

A number of researchers have reported on transpiration efficiencies of various crop species, of which average values are shown in Table 3. From the table, it is clear that the transpiration efficiency of the C_3 crop species is relatively low and about half that of the C_4 species.

Among the C_3 crop species, the transpiration efficiency of leguminous crops, that allow parasitical leguminous bacteria in them, is about 15% lower than the rest.

Based on the values of the table, the amounts of transpiration to produce 1 ton of dry matters are as follows:

C_4 crops	: 315t ;	C_3 gramineous crops	: 599t
C_3 leguminous crops	: 694t ;	Other C_3 crops	: 570t

If we assume that the land-surface evaporation during the growing period is 0.2 of the amount of evapotranspiration, from Equation (6), the demand for water of the farmland needed to produce 1 ton of dry matter is 25% more than each of the above values.

In view that majority of ferrestrial vegetation are the C_3 plants, and assuming the plant community's demand for water is 600t per ton of dry matters, the water resources consumed for each production mentioned above can be estimated as follows. All these water resources are supplied by precipitation on lands.

Potential net primary production:	816,000	(100 million ton/year)
Actual net primary production:	489,600	
Yields of foods and timbers:	73,200	
Production needed for the yields of foods and lumbers:	122,400	

Table 4 shows the water balance of each continent on the Earth. The figures above and in Table 4 suggest that without human activities most of the lands would have been covered by natural vegetation, which would have used about 69% of annual precipitation on earth to produce dry matters. This rate is 10 percentile points greater than the current evapotranspiration rate (58%). For actual net primary production, 41% of precipitation on lands are used, which is about 20 trillion ton less than the estimated amount of evapotranspiration in Table 4. This reflects increases in surface runoff from the bare land areas and in evaporative loss.

According to the data of 1991, approximately 1,870 million ton of grain production required 704 million ha of farmland (including 113 million ha irrigated). Assuming that the total average of harvest indexes is 0.4, the following amount of dry matters must be produced for 1,870 million ton of grain production.

Total Dry Matter Production = 2.5 x 1,870 = 4,675 million ton

If the aforementioned plant community's demand for water (600t of water per ton of dry matters) were applied, 2,805 billion ton of water resources would be used. This means that about 400 mm of water resources are needed for each crop's farming period.

Although this amount is supplied from rainfalls during the period and conveyance from other watersheds, the irrigated farmland area is merely 16% of the total farmland for grain production, as mentioned above.

Table 5 is the scenarios of food for 2050 proposed by Kendall and Pimentel (1994). Increase in the farmland area in them appears quite difficult, as only a 20% increase is estimated even in the optimistic scenario. In the sensible scenario, a 12% decrease is anticipated. Based on the scenarios, the water demand of farmlands is estimated as follows. The figures suggest that the amount of water required to secure sufficient amount of food in the middle of next century, is 30% (pessimistic scenario) to 70% (sensible scenario) more than the current demand for water by the farmland for grain production (400 mm/ha).

Pessimistic scenario : 3.6 trillion ton
Sensible scenario : 4.2 trillion ton
Optimistic scenario : 4.8 trillion ton

Nonetheless, in view of the population expansion, upgrading of living standard, and artificial global warming, we can anticipate the following situations that will add great difficulties to securing water resources for agricultural production.

① Increase in variability of rainfall status associated with global warming. (More shower-type rainfalls, longer dry spells, lower utilization rate of rainfalls, etc.)

② Increase in moisture losses from ground and vegetation-cover areas associated with global warming.

③ Rapid dry-up of the surface of earth.

④ Increase in demand for daily-life and industrial water (especially in developing countries).

On the other hand, an increase in the CO_2 density will improve water use efficiency (W/T, where W = Dry Matter Production and T = Amount of Transpiration), whereby the plant community's demand for water in the farmland is expected to be smaller somewhat than the values used above.

4. Afterwords

The global environment plays the following four roles (functions) against all lives including human beings (Uchijima, 1990).

① To allow creatures to perform activities for living and raise their next generations.

② To produce and store energies and substances necessary for living.

③ To transport energies, substances, and waste products.

④ To decompose and process corpses and waste products to prepare for recycling.

These four major functions are given to the global environment by continuously incidenting solar energy from the sun, the huge amount of water, and behaviour of lives (especially plants) with their history of some four billion years of evolution.

The Earth is, however, exposed in the danger of extraordinary growth and activities of one species – the human race. This danger is brought by "Global Resource Utilization Technology" which has been developed by outstanding performances of the cerebra. This is the system and performance of civilization to regard everything of the Earth (space, phenomena, substances, and lives) solely as resources to enrich our own lives and deplete them. As mentioned earlier, the planet of water – the Earth is the only and safe habitat for all species with their history of some four billion years of evolution, and is the planet that provides various resources for them.

The most important thing, in reviewing the relationship between the global environment and water resources or food production in the near future, is how the human beings and many other species with the weight of 4 billion years of evolution can attain sustainable symbioses on this Earth with limitations. Without drastic controls of materialistic greed of the human beings, this problem would not be solved – it will be difficult to establish sustainable symbioses between human beings and other lives on this planet of water – the Earth.

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Table 1 Contribution of Various Greenhouse-Effect Gasses to the Atmospheric Greenhouse-Effect

Greenhouse-Effect Gas	Volume Ratio (ppmv*)	Infrared Radiation (W/m^2)
Water vapor	0～3000	～100
Carbon Dioxide	350	50
Methane	1.7	1.7
Dinitrogen Monoxide	0.3	1.3
Ozone	30×10^{-3}	1.3
Fluorocarbon (CFC-11)	0.22×10^{-3}	0.06
Fluorocarbon (CFC-12)	0.38×10^{-3}	0.12

*ppm denotes parts per million.

Table 2 Area Frequency Distribution of Net Primary Productivity of Terrestrial Vegetation

(Seino・Uchijima,1992)

NPP range	0～0.9	1.0～4.9	5.0～9.9	10～14.9	15～19.9	20～24.9	25～30
%	22.5	24.7	16.7	10.0	9.7	12.9	3.5

Table 3 Average Water Use Efficiency of Crop Groups (Calculation based on Arkley, 1982)

Unit: grams of dry matters per kilograms of transpiration

Crop Groups	C_4 Gramineous Crops millet, sorghum, corn, and Sudan grass	C_3 Gramineous Crops rice plant, oats, wheat, barley, and rye.	C_3 Leguminous Crops pea, red clover, vetch, alfalfa, and sweet clover	C_3 Crops rapeseed, potato, and cotton
Transpiration Efficiency	3.18	1.67	1.44	1.75

Table 4 Global Water Balance and Water Resources of the Earth
(Listed based on Voskresensky, 1974)

Continents (incl. islands)	Area	Precipitation		Runoff		Evapotranspiration	
	100 million ha	mm	trillion ton	mm	trillion ton	mm	trillion ton
Europe	10.5	789	8.29	306	3.21	505	5.30
Asia	43.48	742	32.42	332	14.41	414	17.98
Africa	30.12	742	22.35	151	4.57	533	16.04
North America	24.2	756	18.30	339	8.20	418	10.10
South America	17.8	1597	28.40	661	11.76	853	15.18
Australia/Oceania	8.95	791	7.08	267	2.39	491	4.39
Antarctica	13.98	177	2.48	165	2.31	0	0
Total/Average	149.00	800	119.00	314	46.80	463	69.00

Table 5 World Food Scenarios of 2050 (Kendall・Pimentel, 1994)

	World Population	Farmland	Output of grains	Average Production Unit
Scenario	100 million	100 million	100 million ton	t/ha
Pessimistic scenario	130	7.04	24	3.41
Sensible scenario	100	6.20	28	4.52
Optimistic scenario	78	8.45	32	3.79

Figure 1 Annual Heat Balance of the Earth

Unit: kcal/(cm²·year)

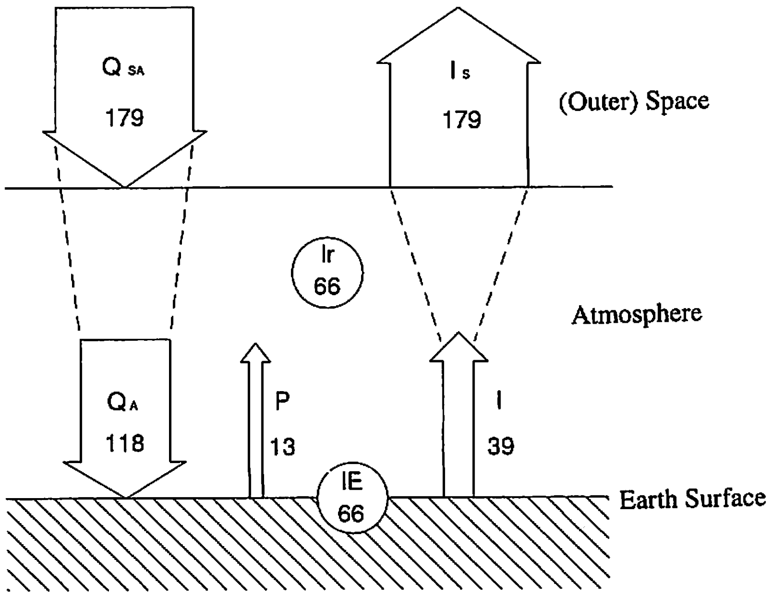


Figure 2 Radiation Energy Balance (a) and Heat transport in Atmosphere and Hydrosphere (b, c and d) per latitude zone

(Diagrams drawn based on Ogura, 1997)

Positive values of the heat transport imply going north; negatives are for going south.

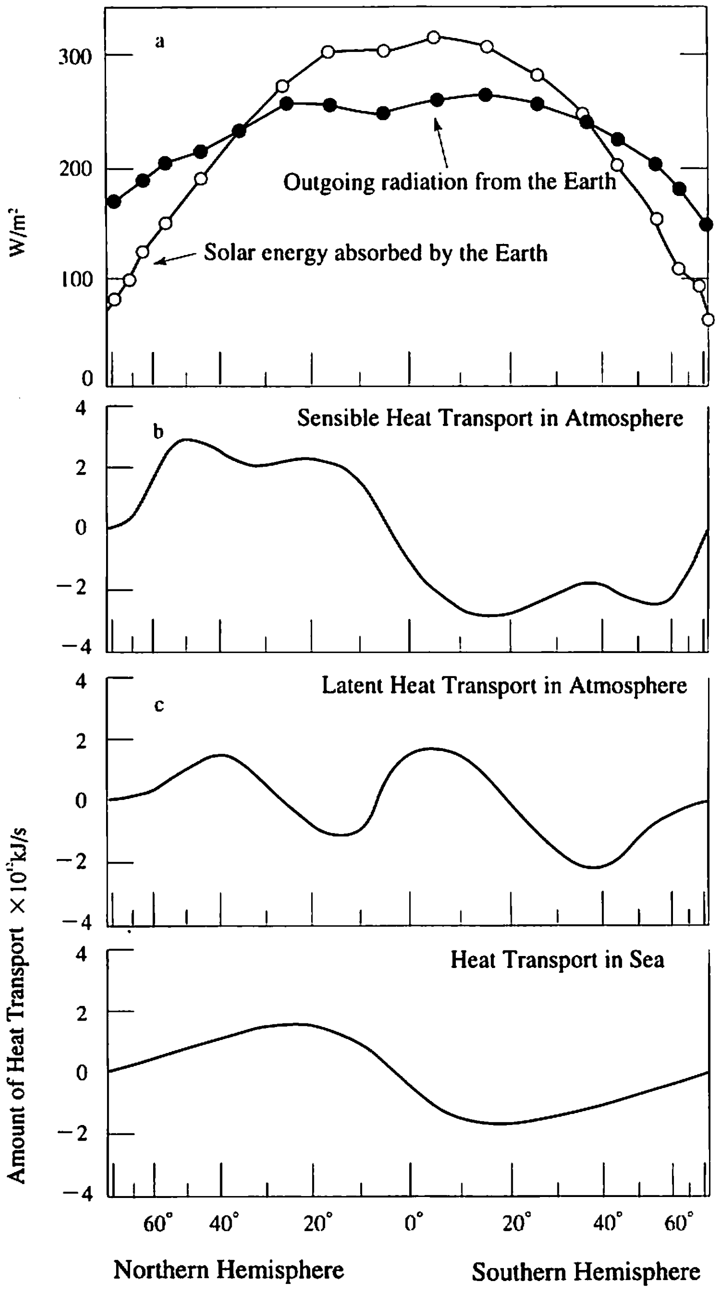
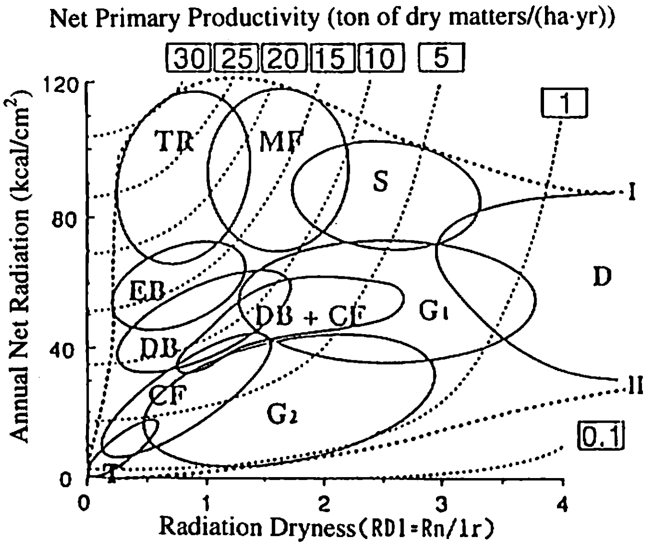


Figure 3 Graphic Model of Environmental Factor vs. Vegetation Distribution vs. Net Primary Productivity (Based on Ohta et al., 1993)



TR: Tropical/Subtropical rain forests, MF: Monsoon forests, S: Savanna, EB: Evergreen broad-leaved forest, DB: Deciduous broad-leaved forest, DB+EF: Mixed forests of broadleaf trees and needle-leaf trees, CF: Coniferous forest, G_1: Warm-temperature zone steppe, G_2: Cool-temperate zone steppe, T: Tundra, D: Semi-desert to desert, I and II: Ceiling and floor values of annual net radiation per climatic zone.

Figure 4 Geographical Distribution of Net Primary Production (t dry matter/(ha·yr)) of Natural Terrestrial Vegetation (Based on Uchijima and Kiyono, 1988)

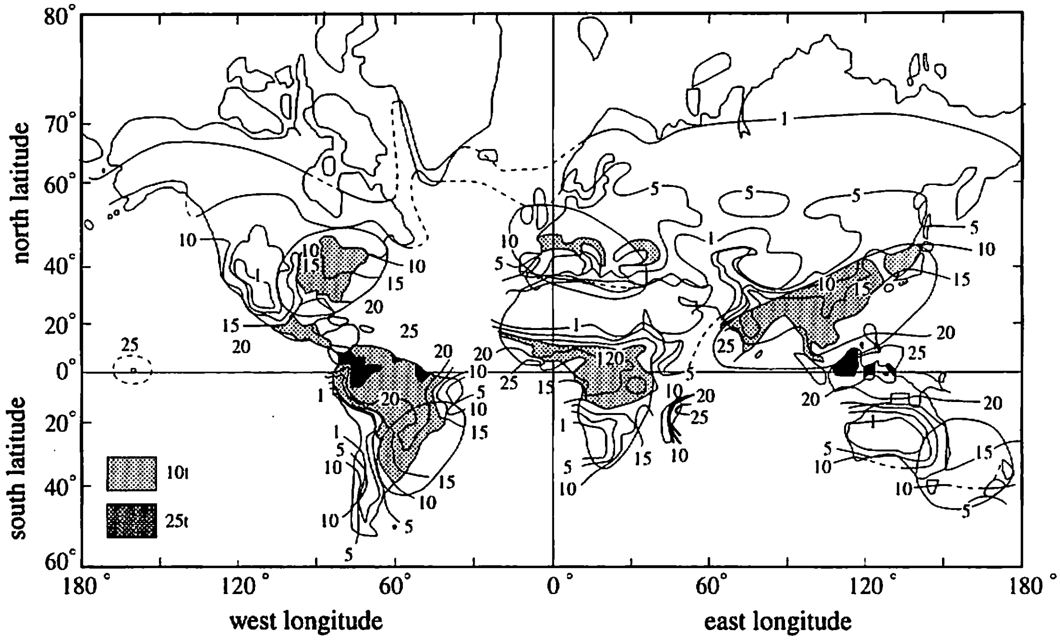
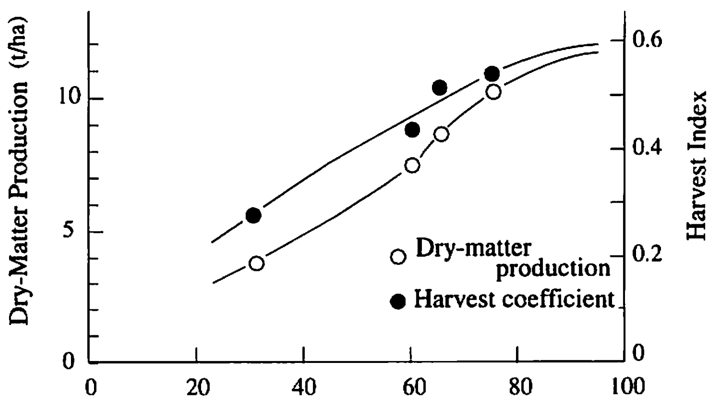


Figure 5 Effect of Soil Moisture to Dry-Matter Production and Harvest Index of Corn Field. (Based on Ustenko, 1963)



Water Content of Cultivated Soil (Percentage figures against field moisture capacity)

Chapter 2

Population of China

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1. Population Policy – Planned Childbirth

China's population policy, including planned childbirth, is characterized by thoroughgoing population control and management, unlike family planning (planned parenthood) as it is often observed in other developing countries.

Full-scale population control began to be implemented in China in the early 1970s, and has continued to be executed. The fundamental aim of the population policy, which is basic national policy, is to control and upgrade the quality of the population. The most remarkable feature of the Chinese population control policy, which is not seen in other countries, is that it is put into effect through a governmental network called the Planned Childbirth Organization, that carries out the central leadership policy at the lowest levels.

To cope with the birth rate problems in the socialist society, China promoted its unique population policy based on "Planned Childbirth" to plan all deliveries throughout the country, with the socialist ideology that the society's total benefit coincides with that of individuals or households. Its planned childbirth policy mainly includes birth control, late marriages, late deliveries, fewer children, and eugenics, and aims to systematically control population growth.

The population policy had taken no less than 30 years to attain favorable results after struggling through the first tentative phases, repeated setbacks, and reforms in implementation.

Looking back on the country's population policy since the establishment of the modern nation, planned childbirth was not implemented in the 1950s, when only the ideology of population control was introduced, while experiment and preparation were carried out. In the first half of the 1960s, the population policy was proposed and began to be put into effect, but was discontinued when the Great Proletarian Cultural Revolution started.

Since the early 1970s, population policy has been formed, gradually completed, firmly established, and has achieved widespread implementation and effectiveness through planned childbirth.

In 1953, the construction of a large-scale economy began. The population census held in the year caused concern over the rapid population growth among the intelligentsia, which then came forward to appeal for population control. For several years after, the concern over the population problem made the necessity of control recognized, and the nation was on the point of making the necessary efforts. The changed political situation, however, suppressed the call for population control after 1958, and many intellectuals were persecuted.

The well-known story of Ma Yin Chu represents the tragedy. In sum, political misjudgment lowered awareness of the population problems as well as efforts for population control, and seriously damaged the economic development almost getting on track.

The radical Great Leap Forward of 1958 failed, and the economic difficulties in the years to follow brought Chinese society into great turmoil. Due to human factors - the economic hardship and social instability, - the population growth rate drastically but temporarily fell, but began a tremendous recovery as the economy revived after 1962. As a result, population pressure aroused public attention, and population control became sought after. In the following year, governmental organizations called planned childbirth committees were formed in several provinces and cities. In 1964, "Planned Childbirth Expenditure" was included in the national budget, and the Planned Childbirth Committee was established in the State Affairs Administration. The population policy, which was just beginning to find its way, was suspended due to the outbreak of the Great Cultural Revolution. During the Revolution, the population problem became taboo, and any discussion on policies for population control was impossible. It was only in the early 1970s that definite childbirth plans for the population policy were introduced and began to be continuously implemented. The issue of population was first incorporated in the national economic development plan in 1973, and the planned childbirth advisory group was formed in the State Council, clearing the way for China's population policy of "planned population Growth".

The population policy during this period was mainly based on the three concepts "Later, Infrequent, and Fewer". "Later" meant late marriages, and aimed at marriages at relatively older ages for men and women. "Infrequent" denoted about four years' interval between two deliveries. "Fewer" implied that no couple would have more than two children. In the meantime, contraceptives and necessary devices began to be supplied free in 1970. In 1973, sterilization, application of IUDs and provision of medical facilities and devices for abortion were introduced in a third of the villages of the country. The Revolution had not yet ended at this stage, but various political means were taken to control population.

The Cultural Revolution lasted as long as ten years until 1976. The new 1978 Constitution stipulated that "the nation advocate and promote planned childbirth", while the defining principle of "one child per couple most desirable, maximum two" was explicitly proposed.

The population policy was characterized even more clearly by a focus on "controlling the population and enhancing its quality". In the following year, it was announced that planned childbirth was one of the basic national policies of China, and the objective was set to control the population of the country within 1.2 billion by the end of the century. The population policy, initially introduced in the early 1970s, took more than ten years of efforts to specify in the Constitution that planned childbirth was a married couple's obligation, by which step China's population policy became firmly established. Since 1980, the policy of "strong recommendation of only one delivery, strict control of second deliveries, and prohibition of more deliveries" has been in force. With regard to "the second delivery", provinces or cities have their own specific rules, allowing some regional differences. While the population policy conducted in China is generally called the "Only

Child Policy", it is, more accurately, an "Only-Child Recommendation Policy".

Through the planned childbirth control network, China's population policy has been powerfully and effectively implemented, and has succeeded in controlling the population. On the other hand, new complex problems have arisen along with the recent great changes in the economy, especially the conversion to the market economy which the government and the people have united to promote. Under the circumstances, the planned childbirth policy has also been facing new difficulties.

There has been no change in the status of Chinese planned childbirth as a basic national policy. As the conversion to market economy proceeds further, it will take a long time to incorporate gradually the current population control policy in social policies in a larger sense, and to lead the policy towards a soft landing.

2. Population Aging

For 20 years after the founding of the modern nation, China maintained a high birth rate. In the 1970s birth control was introduced, and, in addition, the national policy, referred to as the "Only Child Policy", was promoted from the late 1970s to the early 1980s. Consequently, the birth rate has rapidly and continuously declined. The continuous decrease in birth rate has brought about population downturn, and in the process, changed the population structure in terms of age groups, leading toward aging of the population as a whole. The Chinese population's aging is still at a relatively low level, but some regional aging problems are quite acute. It is expected that measures for future aging and regional policies will confront new problems. A notable feature of the aging of the Chinese population is that the aging is going on in a situation in which the economy has not greatly developed, with relatively low income per capita, and in which social security has not been sufficiently established.

The birth rate of China has tended to decline, except for some temporary reverses, for nearly half a century since the founding of the modern nation. Especially, the years since the 1970s have seen sharp drops. The average fertility rate for the 1950s was 5.87, which is almost the same level as the 5.68 of the 1960s. The fertility rate for the 1970s steadily declined to an average of 4.01, and that in the 1980s averaged below 2.50. According to the fourth population census, held in 1990, the national fertility rate is 2.25, with the regional lowest of 1.33 in Beijing, and the highest, of 4.22, in Tibet, which is almost double the national average. The birth rates in about a third of the regions of China were so low as to fall under the population replacement level.

Along with the decline in birth rates, mortality rates have also decreased, pushing up the average life expectancy of the population. The average life expectancy of Chinese men was 55.8 years, and that of Chinese women was 55.9 years. These increased to 66.3 years and 69.3 years respectively in 1981, then to 67.6 years and 70.9 years in 1990.

Sustainable rapid decline in the birth rate and continuous growth of life expectancy together imply fast aging of the future Chinese population. Various regional differences in age structures are seen in China. Migrations between urban and rural areas could be one reason, but a more important factor is considered to be the birth-rate gaps. Although aging of the Chinese population, as a whole, is still relatively minor, differences between urban and rural areas, or between regions, are rather great. The population's aging is expected to develop very fast in the years to come, and the reason for that is the continuous decline in the birth rate, which is a result of the population control carried out over more than 20 years.

Due to the declining birth rate under the population control policy, the age structure of the population has varied. As the composition of the Chinese population shows in the Table 1, the oldest age group of 65 and above accounted for 5.6% of the population in 1990, and increased to 6.7% in

1995, while the population index of old people reached 10% in 1995. The United Nations medium variant estimate ("World Population Prospects: The 1996 Revision") forecasts that the oldest age group of 65 and above in China will account for 10.8% of the total population in 2020, 14.4% in 2030, and 19.2% in 2050.

Although the aging level in China is still lower than that in developed countries, substantial regional gaps are seen within the country. For example, in 1995, the rate for the oldest age-group of 65 and above averaged 6.7% nationwide, whereas that in Shanghai, where the aging pace is fastest, accounted for 11.4%. Since the national population itself is of a large scale, the old age population is also naturally enormous, as well. According to the United Nations' medium-variant estimates, the population of 65 and above (in China) is estimated to reach 85.5 million in 2000, 156.47 million in 2020, and 215.96 million in 2030. Such an immense elderly population will, without doubt, bring society many problems in the area of medical or health care and nursing, etc.

In China, where population control policy has been implemented, the birth rate is already quite low, and population growth will continue to be controlled by the "Planned Childbirth" basic national policy. Therefore, the birth rate is unlikely to rise so much as to make substantial changes in the age structure of the population. Consequently, it is inevitable that drastic aging of the population will occur in the near future, provided that the birth rate will continues to be low as it has been to date. Along with population aging, the establishment of social security systems, such as medical care, pension plans, etc. will have to be promoted. Rapid aging of the population will strongly impact on development of the society and the economy. The population aging expected in the future may lead to reconsideration of the population policy for the future.

China will be facing rapid aging of society when the economic level is still relatively low. Currently, about 80% of the elderly population of China is not covered by pension plans, and social security for old people is limited to only part of the aged population. According to the research conducted in 1991 by the Research Center on Aging, 72.9% of the elderly urban population received benefits, whereas only 5.7% of the rural old population did so. Today, the actual living standards both in urban and rural areas are low, with great gaps existing between those areas, between age groups, and between the sexes. In reality, many old people are dependent on their families. In view of the current situation in China, it is impossible in the short term that the nation will solve the problem of supporting its old people, although it is hoped, as society and the economy develop, that society will increase pension funds and establish a social security system.

In 1995, China formally declared a policy in which an annuity insurance system would be implemented by linking the society unification plan with individuals' accounts.

All laborers, who have taken out the annuity insurance policies, are to open individual accounts, in which the insurance fees paid by themselves, as well as part of the fees paid by their employers for them, are recorded. Part of the fees paid by corporations will become social unified funds to pay annuities to the retired. The objectives are, by the end of this century, to increase the annuity insurance coverage and fund sources, implement various annuity insurance plans, and establish a comprehensive annuity insurance system combining the laborers basic annuity insurance, the corporate supplementary insured pension plan, the social unification plan, and individual accounts.

Currently, a number of regions nationwide are conducting their annuity insurance schemes on the basis of on the principle of combining the social unification plan with individual accounts. The coverage of the social unification plans differs between regions; some unification plans are implemented by provinces, and others by cities. Actual situations also differ between areas; some local populations established social insurance institutions to make the annuity insurance belong to local society itself, while other authorities let corporations pay pensions as they have in the past. In the meantime, the national scheme for annuity insurance is under the control of several bodies. For example, the Department of Public Welfare manages annuity insurance in the rural areas, the Department of Labor (before reform of the organization) urban wage-earners' annuity insurance, and the Personnel Department civil servants' annuity insurance. There are also several insured pension plans industry-by-industry.

Along with the progress toward the market economy, further reforms and tentative steps towards an insured pension scheme will continue in China.

3. Future Population Trends – Population Growth

At the time of founding the modern nation in 1949, the Chinese population was about 540 million. It passed 1,140 million in 1990, and reached some 1,236 million at the end of 1997. The population increase over nearly half a century has been almost 700 million, or an increase of 2.3 times expressed by rate. The annual increase in the seven years between 1951 and 1957 was 2% or more, but population growth stagnated between 1958 and 1961. The year 1960 even saw negative population growth, never before seen in the modern nation.

Such stagnation and decrease of population growth during these periods was intimately linked with factors like natural disasters.

After several years of slowdown, the Chinese population instantaneously regained active growth, and marked a 3.3% increase in 1963, the highest rate since the nation was founded. The population increase did not lose speed after that, and maintained more than 2% per annum natural growth rate between 1962 and 1973. The natural growth rate went below 2% for the first time in 1974 among normal years. Thereafter it gradually declined, and fluctuated at annual averages between 1.1 and 1.4%, but edged up again in the latter 1980s. That edge-up was due to the echo effect from the long and fast population growth from the 1960s to the early 1970s. In the 1990s, the growth rate has been about 1.1% annually. The decline of the Chinese population growth-rate, and the continued trend of such, since the latter half of the 1970s, apart from the slight rebound, is obviously the result of the population control policy implemented since the early 1970s.

In 1998, China has set forth new objectives for population and planned childbirth policies to the end of the century, and up to the middle of the 21st century. The first objective is to keep the Chinese population within 1.3 billion until 2000; the second is to control it within 1.4 billion until 2010; and the third is to lead the peak national population of the mid 21st century (estimated at around 1.6 billion) to a gradual decline. The country's fertility rates have been under the replacement level in recent years. However, due to the scale of the population, about 20 million babies are born every year, and about 13 million net annual increase has been maintained. Under the circumstances, the Chinese population is expected to increase by 400 million over the next several decades.

According to the UN Prospects, as shown in Table 2, the population China is not seen as exceeding 1.3 billion by the end of this century. It will approach 1.4 billion by high-variant estimate in 2010, but could be a little over 1.36 plus by medium-variant estimate or a little under 1.33 billion by low-variant estimate. Thus, the population is estimated, by any of these three methods, to be within the target limit for 2010 which the country aims at. In the meantime, it will go above 1.7 billion by high-variant estimate in 2050, or above 1.5 billion by medium-variant estimate, but under 1.2 billion by low-variant estimate. The population is expected to continue to grow until 2050 by high-variant estimate, but could be turning to a slight decline in or after 2040 by medium-variant estimate, and the speed of the decline could be even faster by low-variant estimate after 2030.

In any event, the future trend of the population growth in China depends on the continuing planned childbirth policy, i.e., the process of implementation of the population control policy, and the variation of the birth rate as well as the mortality rate.

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Table 1 Transition of Age Structure of Chinese Population

(%)

Year	Age Structure Factor			Independent Population ratio	Younger Generation Population ratio	Elderly Population ratio
	0 ~ 14	15 ~ 64	65 & above			
1953	36.3	59.3	4.4	68.6	61.2	7.4
1964	40.7	55.7	3.6	79.4	73.0	6.4
1982	33.6	61.5	4.9	62.6	54.6	8.0
1987	28.8	65.7	5.5	52.5	44.1	8.4
1990	27.7	66.7	5.6	49.9	41.5	8.4
1995	26.7	66.6	6.7	50.2	40.2	10.1

Source: based on Annual Population Census Results

Note: The figures for 1987 and 1995 are results of 1% sampling surveys.

Table 2 Estimates of Future Population in China

('000)

Year	High-Variant Estimate	Medium-Variant Estimate	Low-Variant Estimate
2000	1,282,676	1,276,301	1,269,927
2010	1,394,253	1,364,950	1,329,683
2020	1,509,389	1,448,818	1,366,031
2030	1,607,984	1,499,782	1,353,039
2040	1,689,571	1,518,172	1,292,656
2050	1,765,222	1,516,664	1,198,215

Source: World Population Prospects: The 1996 Revision, United Nations

China's Water Resources Facing The Millennium

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A Word at the Gate

Our pending entry into the 21st century and the third millennium is in reality the crossing of an imaginary threshold with no intrinsic meaning except to our computers. Nonetheless, it is a good time to reflect, especially about the past that we know and the future that fresher generations must face. The past fifty years in particular have been extraordinarily dramatic ones for China and India, politically, economically, demographically, and in terms of resource use and abuse. The next fifty years promise equal or greater drama, but played out under vastly different rules, and with uncertainty as to whether it will be a romance or a tragedy.

Here we speak of water. The progress of the past half-century in agriculture, industry, energy, and urbanization has largely been premised on increases in water use, unconstrained by the discipline of the market. Growing limits on resources-- hydrological, environmental, and financial -- are likely to change the character of development in the coming decades. Furthermore, the floods that savaged China and south Asia the summer of 1998 served as a reminder that scarcity is not the only water problem left unresolved by the twentieth century.[1]

Indeed, water nourishes and water destroys. It constrains development when it shows up in surfeit as well as in deficit, and when first users befoul it or waste it in low-value uses. Complicating control further is the interconnected nature of these different problems. For example, when water is short but wasted, it is likely to be polluted. When river flows fail to carry silt to sea, channels rise and ever smaller volumes of runoff can create ever nastier floods.

The many faces of water have constrained the economic histories of China and India. Some have even claimed that they stifled political development in the region by giving a stable but stifling pre-modern bureaucracy its raison d'être.[2] Political and technological reforms of the waning half of the 20th century brought with them the hope that waters could finally be controlled and directed to fulfill the needs of a growing population, and that this could be done largely by relying on state-subsidized project-based public works. As in most of the rest of the world, there are strong signs that this strategy needs to be reconsidered.

This introduction to China's water resources first compares the conditions in China and India, the countries of primary concern to the present volume. It then discusses water use by sector and current projections into the next century. Finally, it touches on two areas where stresses are already beginning to show: the Huang He (Yellow River) and urban water supply.

1. Comparing China and India

The populations of China and India, already comprising over half the third world, are growing and growing closer in size. In many ways both substantive and superficial, the two countries are also quite similar when it comes to water and its uses (Table 1). China is virtually tied with Canada as the third most water-abundant country in the world (after Brazil and Russia), while India is seventh, after Indonesia and the United States. Because of their different populations, per capita water is only slightly higher in China (2,200 cf. 2,100 cu.m./cap./ann.). Both are well below the world average of 6,900 cu.m., but above the 1,000 cu.m. per capita that is commonly used as a rule of thumb to indicate serious water stress.

Nonetheless, there are regions within both countries that do already fall well under the 1,000 cu.m. per capita level. In China these include the Huang He (Yellow River) basin (593 cu.m. in 1990)[3] and the overlapping north China region comprising Beijing, Tianjin, Hebei, Nei Monggol, Shanxi, Shandong and Henan (556 cu. m. in 1990).[4] In India, river basins comprising most of Tamil Nadu and Andhra Pradesh states in the south and Gujarat and southern Rajasthan states in the west, are identified by the Tata

Energy Research Institute as suffering from scarcity (below 1000 cu.m./cap.), or absolute scarcity (criterion unclear).[5]

In both countries, over three-quarters of water used is devoted to irrigating a nearly identical area of roughly 50 million hectares. Even the crops produced in the two countries are broadly similar, with rice accounting for about 40% of grain output (one difference is that China produces twice as much as India). In both, irrigated area increased considerably after 1970 due to the installation of powered tube wells in their northern wheat growing areas (Hebei, Shandong and Henan in China, the Punjab in India).[6]

Two-thirds of the population in both countries still live in the villages. This means that urbanization pressures are unlikely to abate until well into the next century. Currently about one in ten inhabitants resides in the largest cities. With the growth of megalopolises of unprecedented size, and rising economic output, will come new non-agricultural demands for water. Already, it is difficult for urban infrastructures to keep pace with existing demands on water supply and treatment.

2. Uses by Sector, Now and Henceforth

There are a number of different estimates within China regarding future water use. Table 2 provides breakdowns of actual water use in China in 1990 and projections for the years 2000, 2010, and 2030, made originally by Chen Jiaqi (陳家寄) of the Ministry of Water Resources. These are divided by three major sectoral categories: agriculture, industry, and municipal. "Agriculture" refers only to the amount that can be supplied for crop irrigation, and is assumed to be 9-16% below demand. Other rural uses are not included, such as drinking water for people and livestock, pasture and fishery, and rural industry. These are only a small fraction of water used in irrigation, but are much higher than municipal uses. Industrial uses include thermal power generation, which has taken about half the total but is expected to decline in the future.

Irrigation is expected to dominate water use in China at least through the year 2030, by which time Chen sees industrial uses pulling nearly even. Others, however, see agriculture maintaining its dominance in perpetuity, holding at 500 billion cu.m. from 2030 onward while industry stabilizes at 200 billion cu.m. about the same time. Total water use is seen as peaking at about 800 billion cu.m. in the 2070s, using roughly a quarter of the total water resource (see Figure 1). There are two important elements in these admittedly rough calculations: that water use efficiencies continue to improve considerably in both agriculture and industry, and that population stabilizes about the year 2050.[7]

With these optimistic but realistic assumptions, it would seem that, at least in quantity terms, China as a whole will not find water to be a significant constraint to development. The situation may look different for those parts of the country that are already facing widening gaps between demand and locally available supplies of water of adequate quality. It is to some of these critical sectors that we now turn.

3. The Sick River

The Huang He is a long river with relatively little water and a lot of silt. It is estimated that in 1990 nearly half its annual runoff was used consumptively (without being returned).[8] Flow to the sea stopped during the dry season in 20 of the 26 years between 1972 and 1997, including every year from 1991 on. The trend has been towards increasing severity of cutoff, leading some Chinese to term the Huang He a "sick river".

In 1997, there were 11 stoppages for an unprecedented total of 222 days, with the first occurring on 7 February. Even during the wet season (June through September), the river flowed to the sea for only 14 days.[9] The severity of the stoppage in 1997, which reached 703 km inland to the outskirts of Kaifeng, was magnified by extremely low precipitation, in some cases the driest year since 1951.

Nonetheless, growing demands on the river's water, both upstream and downstream, have been the principal factor behind what has now become a perennial shortage. There are a total of 122 projects diverting up to 4000 cu.m./s. from the Huang He in 85 counties and municipalities to irrigate over 8 million hectares of land. These include some very productive cotton, tobacco and rice fields on the north China plain. In addition, water-short cities such as Qingdao on the dry Shandong peninsula have come to rely on diversions from the lower reaches.

Table 3 shows the history of withdrawals from the Huang He. By the 1980s, there was concern that not enough water was being left in the river for environmental purposes, notably to discharge silt into the ocean. A decade later, withdrawals in the upper reaches began to affect the total available downstream as well. The State Council issued a nonbinding allocation of water among the 11 provinces and municipalities using the river, but it was set in absolute, not proportional amounts. In effect this favors upstream users in a time of drought.

Nonetheless, some argue that it is excess withdrawals within Shandong Province, the final and heaviest user, that is a major contributor to the problems of the Huang. In addition, a sort of vicious cycle appears to have developed where localities draw off water and store it in anticipation of cutoffs that their actions help precipitate.

The upstream-downstream conflict in the Huang basin is to some extent one between equity and efficiency. Upstream provinces tend to be very poor, but also to use very high amounts of water at heavily subsidized prices to water low-value grain crops and at the same time aggravate problems of soil salinization. Downstream provinces are principal beneficiaries of the post-reform economic boom, and tend to use water for higher value crops or off-farm purposes. They also pay a higher charge for water, although still not enough to cover full cost.

Suggested countermeasures to the flow cutoffs include more rational pricing, promoting water conservation, changes in upstream reservoir operating rules and other forms of improved basin-wide operation, importing water from the Yangtze, creating more off-stream storage, and encouraging more conjunctive use of surface and ground water. None of these solutions will be easy. Most depend upon whether China can develop adequate pricing and entitlements systems for surface water that are responsive to changes in natural conditions and the value of alternative uses.

4. Thirsty Cities

Roughly two-thirds of China's 600 cities are considered to be short of water. Just over 100 of these are "seriously" short (data released in 1997). The largest cities are the most affected: 51 of China's 61 cities over 100,000 population were water short in 1990. Regionally, northern China's cities and the rapidly growing coastal cities located in small basins tend to be the most affected.

The primary cause of urban water shortage is that water supply projects have not kept pace with the growth of the cities. This is followed closely by demands exceeding the capacity of the local water sources. Some cities, especially along the lower Yangtze, are water short because of pollution of their water source, primarily because of urban and industrial effluents. These constituted 42%, 38% and 6% of the 109 water-short cities (of 189 total) at the prefectural-level and above in 1990, with the remaining shortages of mixed nature.[10]

Water shortages are said to "affect" 230 billion yuan (4.1 trillion yen) of industrial production each year. This is roughly 2% of total output, but could be as much as 5% if it refers only to state-owned enterprises. It is not clear that this kind of figure has much economic meaning as a measure of constraint to development, however. Industrial production has continued to grow rapidly in recent years, even in some of the most affected cities, such as Tianjin, Taiyuan and Beijing. Industrial production "lost" is a measure of the potential gains from providing a more secure supply of water or investing in improved storage and water-saving facilities, not of an absolute limit to growth.

In many cases, the constraint is one of finance more than of water. This limit in turn is exacerbated by the lack of adequate cost recovery for public water supply and sewerage facilities. The Chinese government appears to have made a serious commitment to making "economic" projects self-financing with the issuing of a *Water Sector Policy* at the end of last year. Since irrigation projects are considered to be not "economic," this new policy is likely to favor the development of urban and industrial water supply investments.

In practice, the response of many of China's cities to chronic water shortages has been to tap local sources that would otherwise go to nearby farmers for irrigation. In Beijing and Shenyang, this has meant transferring surface water from reservoirs. In many other cities, especially in southern Hebei Province, urban users have relied on wells to draw groundwater from ever-receding depths, creating "cones of depression" that can extend over thousands of square kilometers. The situation is particularly grim in Hengshui and Cangzhou municipalities, and Dezhou in neighboring Shandong, where water is drawn from deep aquifers over 50 meters deep and also has a high natural fluoride content that can be hazardous to the health when used for drinking over long periods of time.[11]

The lowering of the water table raises the pumping costs to nearby farmers when they also have to rely on wells. Nonetheless, irrigated area and grain production have increased in Hebei in recent years.

A Word at the Outlet

As in other twentieth-century countries, China has relied on claiming an increasing share of the available water supply to support economic development, using projects such as large dams and diversions and tubewells. That time is coming to an end, first of all in the marginal areas such as the Huang He and for the groundwater users of Hebei Province. So far, the non-sustainabilities of current patterns of water use have apparently not restricted development appreciably, however.

There are two ways of interpreting this situation. One is that China's current mode of development is leading to greater exposure, and merely postponing the catastrophe – the view that the drama of the next century will be filled with tragedy. The other is that institutions will show adequate adaptability to avoid the tragedy, but that water will have to be treated as an economic good. This could cause some sad stories for those who live on the margins—not a romance or a comedy, but not a tragedy, either.

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1 At the time of writing, China had reported 3,004 killed in flooding, India 2,353 (The Japan Times, 29 August 1998: 4) and Bangladesh 407 (The Independent Internet Edition, 31 August 1998). The flooding along the Yangtze was the worst since 1954, when 33,000 died, while in the northeast the Daqing oil field, China's largest, was flooded. Bangladesh was inundated with its worst flood in 10 years.

2 The most extreme example of this view was the "Oriental despotism" of Karl August Wittfogel. More moderate views are widely accepted that an "Asiatic mode of production" based on irrigation or river control led to the perhaps premature development of a bureaucratic state that may have been a factor hindering the indigenous development of an industrial revolution.

See, for example, Mark Elvin et al., Japanese Studies on the History of Water Control in China. Canberra: Institute of Advanced Studies, ANU, 1994.

[3] Chen Yongqi, Wang Tiemin and Qiao Xixian, eds., Huanghe liuyupian queshui chengshi shui ziyuan gongxu yuce (Supply and demand projections for water resources in water-short cities in the Huang He basin). Zhengzhou: Huanghe Shuili Chubanshe, 1997: 11.

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[5] P. William Reidhead, Suchi Gupta and Deepti Joshi, eds. State of India's Environment Report (A Quantitative Analysis). New Delhi: Tata Energy Research Institute, 1996: 12-13. Rajasthan had a per capita water availability of 562 cu.m. in 1990, comparable to north China. Sustaining Water, Easing Scarcity: A Second Update. Washington, D.C.: Population Action International, 1997.

[6] Bangladesh experienced a "groundwater revolution" in the 1980s and early 1990s with the installation of shallow tubewells. Mark W. Rosegrant, "Water Resources in the 21st Century: Increasing Scarcity, Declining Quality, and Implications for Action". UNU/IAS Working Paper No. 3. Tokyo: United Nations University, 1996: 15.

[7] Liu and He, 1996: 101.

[8] Huanghe liuyu shuihan zaihai (Flood and drought disasters in the Huang He basin). Zhengzhou: Huanghe Shuili Chubanshe, 1996: 14.

[9] Ke Lidan, "Huanghe xiayu duanliu yuanyin fenxi ji duice yanjiu" (An analysis of the causes of flow stoppage in the lower reaches of the Huang He and a study of countermeasures), in Shuilibu Shuizheng Shui Ziyuan Si, Huanghe duanliu ji qi duice (Flow stoppage in the Huang He and its countermeasures). Beijing: Zhongguo Shuili Dianli Chubanshe, 1997: 34; and Huanghe queshui xingshi ji qi duice. Beijing: Shuilibu Shuili

Xinxi Zhongxin, 1997: 1-2.

[10] Zhongguo shuihan zaihai (China's flood and drought disasters). Beijing: Zhongguo Shuili Shuidian Chubanshe, 1997: 400-401.

[11] This sort of "natural" pollution by geochemical processes affecting groundwater has also been identified recently as a major health problem in areas of Bangladesh and West Bengal that rely on groundwater containing arsenic for human consumption.

Table 1. Similarities between China and India

	China	India
1. Population (1998)	1,255,091,000	975,772,000
2. Estimated population (2050)	1,516,664,000	1,532,674,000
3. Cultivated area (ha) (1994)	130,000,000	169,700,000
4. Predominant grain crops	Wheat and maize in north, rice in south	Wheat in north, rice in south
5. Irrigated area (ha.) (1992-94)	49,806,640	49,213,000
6. Population in cities over 750,000 (1995)	12%	11%
7. Annual renewable water resources (cu. km.)	2,800	2,085
8. Ibid. (per capita, cu.m.)	2,231	2,137
9. Annual withdrawals (cu. km.)	460 (1980)	380 (1975)
10. Ibid. as percent of resource	16.4%	18.2%
11. Sediment discharged to ocean (million metric tons per annum)	2,010 *1,080 of which from the Huang*	1,956 *1,670 of which includes Bangladesh*

Sources: *World Resources 1998-99*, 1998: 245 (1, 2), 287 (3 [India], 4), 175 (5), 305 (6, 7, 8, 9); Peter H. Gleick, ed., *Water in Crisis*, 1993: 156 (10).

Table 2. Projected water use by sector (in billion cu.m.)

	Agriculture	Industry	Municipal	Total
1990	440.0	50.0	10.0	500.0
2000	470.0	115.3	16.7	602.0
2010	500.0	181.2	23.0	704.2
2030	500.0	478.3	36.5	1014.3

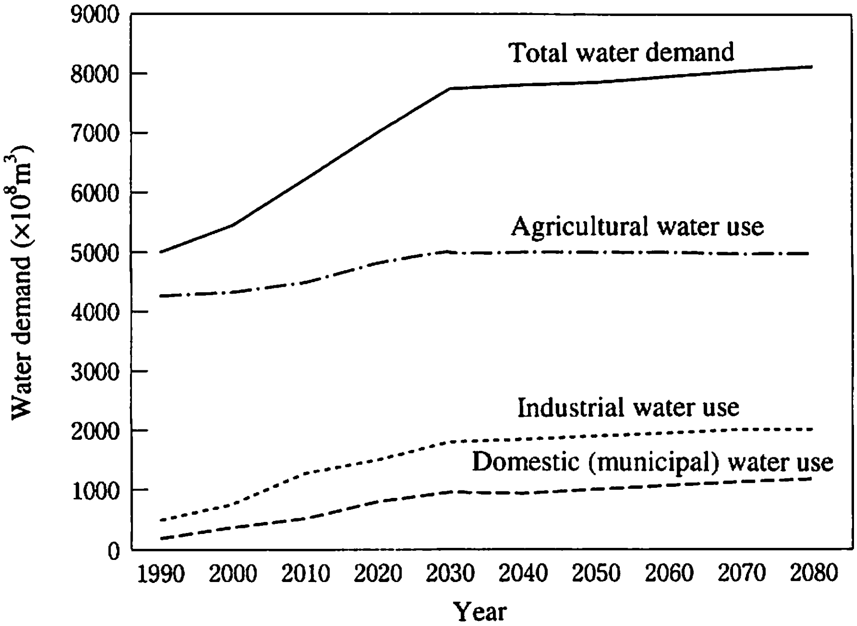
Source: Liu Changming and He Xiwu, 1996: 93.

Table 3. Average annual water use in the Huang He by decade (in billion cu.m.)

	Upper reaches	Middle reaches	Lower reaches	Total
1950s	7.34	3.00	1.89	12.23
1960s	9.52	4.94	3.31	17.77
1970s	10.29	6.34	8.35	24.98
1980s	12.11	6.21	11.29	29.61
1990s	13.17	6.02	10.78	29.96

Source: Shuilibu Shuili Xinxi Zhongxin, 1997: 8. "Upper reaches" are upstream from Toudaoguai in Inner Mongolia just before the river turns south; "lower reaches" are downstream from Huayuankou near Zhengzhou, Henan.

Figure 1 Water demand projection, 1990 - 2080



Source: Liu and He, 1996: 101.

Sustainable Development and Conditions of Population, Food and Agricultural Development in China

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1. Introduction

Studies on sustainable development are already in the forefront of leading international scientific themes, and represent one of the basic principles to which countries give priority in preparing their development plans.

While the Chinese economy has been achieving remarkable development, its fundamental conditions, such as unceasing population growth, limited per-capita resources, pressure on the ecological environment increasing day by day, and fluctuations of long-term development, imply that the economy must take a sustainable development path characterized by Chinese-specific features. High-level consistency between population, resource, environment, and policy making factors will be the key to the harmony between human beings and nature.

So called development is the track of actions taken in a complicated system comprising nature, society and economy. This vector is considered to lead such a system in a more balanced, harmonized, and complementary direction. Under this definition of development, emphasis is placed on its irreversibility, breadth, and on the complexity of nature, society and economy. Accordingly, the term, "development", is treated as a clearly positive and beneficial process, and can be a base on which the healthiness of economic and social situations in different phases are diagnosed, inspected, and adjusted. Therefore, the author will attempt to discuss sustainable development from the viewpoints of population, food production, and agricultural development in China.

2. Case Study Analysis of Population and Labor Resources in China

1. Population Expansion

The population problem is the long-term constraining factor on China's development today. An unprecedented phase of the population expansion in this country began along with the onset of industrialization in the 1950s. According to projections, the national population will increase to 1.3 billion in 2000, and reach its peak of 1.62 billion in 2030.

This growth could be on an even longer scale, should the planned childbirth (family planning) policy be relaxed even slightly. Concurrently, the country will be confronted with the peaks of the old population and the labor force population. The old population of 65 and above is expected to increase by 200 million, and exceed 300 million in 2040, which will account for about 20% of the total population of China, requiring unusually great efforts to support it. On the other hand, the labor force population between the ages of 15 and 64 will reach its peak of some 1 billion in 2020. The actual supply of labor force is estimated to be between 800 million- and 850 million- sstrong, which will create employment pressure in the long run. The three northeast provinces see a similar trend.

2. Case Studies on Labor-Force Growth and Working Conditions in the three Northeast Provinces

(1) Current Situation in the three Northeast Provinces

The total increase of the labor force in all over China has been observed as follows. In 1990, the total labor force population was 697.32 million, including 567.40 million social laborers, and the annual rates of increase were 4.2% and 4.6% respectively. According to projections, the rate of annual increase in labor population in China in the 1990s has been about 3%, and additional new employment opportunities have been required by, on average, about 15 million people each year. The most prominent issue regarding employment pressure is the immense excess labor force in rural areas. By statistics, agricultural excess laborers accounted for about 140 million in 1988. As the rural populations increase while the scale of planted land decrease, conversion from rural excess labor force to the non-agricultural labor is considered to be the fundamental objective in realizing industrialization and urbanization in China.

Results of the fourth population census showed that the total population of the three northeast provinces in 1990 to be 99,336,000[1)] including 64,333,000 of the population of productive age, which comprised 64.8% of the total population. Of this working-age population, the employed workforce was 52,696,000 or 81.9%.

According to the statistics, it is clear that the proportion of the productive age group to the total population of the three northeast provinces in 1990, 64.8%, is higher than that of the country as a whole, which was 60%. With regard to the increase in the productive-age population of the three provinces (See Table 1), up to 1964, the growth of the total population was more remarkable, whereas since 1964 the speed of increase in the productive-age population has substantially exceeded that of the total population. This is because the second-generation baby-boomers born in the 1950s and 1960s are now part of the productive-age population.

Meanwhile, due to the implementation of the planned childbirth policy since the 1970s, the birth rate has decreased considerably, and as a result, the total population growth rate greatly declined in 1990.

The age structure of the productive-age population in the three northeast provinces represents a remarkable increase in the proportion of young population (See Table 2).

Table 2, which is the result of the fourth population census held in 1990, implies that more than 80% of the productive-age population in the three provinces are in their youth or prime, implying ample labor resources.

Table 3 shows the industrial structure of the employed workforce in the three northeast provinces in 1990. The proportion of the agriculture, forestry, stock farming, and fishery workforce is extremely high. The industrial structure consists of 52.7% represented by the primary industries, 27.2% by the secondary industries (manufacturing and construction), and the merely 20.1% of the tertiary industries (all the rest other than the primary and the secondary).[2)]

(2) Projection of Future Labor Force in the three Northeast Provinces

With the aid of data from the population census, the total and workforce populations in the three northeast provinces from 1990 through 2010 have been estimated.

The actual estimates were obtained from each province, and the totals for each item for each province are shown in Table 4.

As clearly observed in Table 4, the total population of these provinces is expected to increase to 109.12 million in 2000, 67.9% of which represents 74.07 million of the productive-age (15 to 59) population. In 2010, the total population will be 115.03 million, and the productive-age population will be 79.59 million or 69.2% of the former. Likewise, in the next 20 years or so, it is expected that the labor resources in the three provinces will continue to be abundant. The scale of the productive-age population and the age structure are results of the various of birth rate and mortality rate in the past.

(3) Increase of Labor Force in 1990s

In the three northeast provinces, the total productive-age population is considered likely to increase by 16.22 million to 74.07 million before 2000, and by a further 16.53 million to approx. 80 million (79.58 mil) toward 2010. Consequently, the labor force in these provinces has the following features at the present time.

Firstly, the 1990 productive-age population in the provinces was 64.33 million, in which the actual employed are 52,70 million denoting an 81.9% utilization rate of the labor resources. Even if the utilization rate was assumed to be 85%, subtracting the proportion of students and soldiers – 10% from the productive-age group, - still 1.98 million people would remain unemployed. In the 1990s, 1.46 million new job-seekers must be employed each year and, in addition, at least 200,000 of the employed (as a result of an increase in the employment rate) must be found positions each year. Thus, on average about 1.60 million of labor force have requested for employment every year. In other words, on average the additional supply of labor force per year has been 1.60 million.[3)]

Secondly, the employed population of the three provinces was 16.486 million in 1990. The employment condition under the state-ownership policy (through government agencies, corporations, etc.), mean that a certain number of the employed are virtually excess labor, and the number of such potential unemployed is estimated to be 3.30 million.

The problem of excess labor will become increasingly critical as the economic development in the three provinces promotes conversion of industrial structure and urbanization, and as the diffusion of agricultural automation pushes up productivity.

3. Problems in Employment of Labor Force in the three Northeast Provinces

As mentioned above, the situation regarding the labor force in the three northeast provinces is that the resources are abundant in quantity, but of low quality. Such a labor force, together with an irrational industrial structure, in the three provinces has more or less impacts upon their economic development.

The large-scale annual increases in the labor supply need to be coped with by an appropriate number of workplaces. For example, the total productive-age population of the three provinces will reach 74.07 million, representing an increase of 9,733,000 from the 1990 level, or an average of 974,000 per annum. Assuming the utilization rate of the 1990 labor resources (81.9%) is maintained, the increased supply of labor force will be

60,663,000-strong in 2000.

If this is the case, 7,975,000 more job opportunities, compared to the 1990 level, need to be created. The respective situations in urban and rural areas are as follows.

(1) The rural villages in the three northeast provinces have long been of a single agricultural structure. Increases of labor force were constrained by the fixed areas of farmland, and were not sufficiently used as labor resources. Many of the labor force have moved from agriculture to non-agricultural industries since the reform of the rural economy system, especially by the implementation of household-based contract production. Nonetheless, those rural villages still hold an enormous amount of excess labor force. According to a survey of rural villages in 10 prefectures counties of 8 provinces, the proportion of the excess labor force in agriculture is about 40%. The labor force in the rural areas in the three provinces in 1990 amounted to 19,533,000 or 43.5% of the total labor force. The combined farmland area of the three provinces is 24,358,000 Mu.[4) If farming machines are introduced in the farmlands, of which the per-capita area is estimated to be 12.47 Mu, only 12,179,000 heads of labor force would be sufficient. In that case, the rest 7,357,000, would be excess labor force.

(2) The problem of the unemployed in urban areas is also obvious. The number of unemployed people in the three provinces in 1990 was about 900,000. Jilin Province alone currently has 200,000 of the unemployed, since those born in the 1960s and 1970s all belong to the productive-age population. However, the Government can only provide 40,000 people with job opportunities every year. During the eighth 5-year plan period (1991-1995), an dditional 1.10 million joined the productive-age group, which means that the additional population available for employment, excluding students, etc., was 150,000 to 160,000 each year.

3. Potential Strength of Chinese Agriculture and Conditions of Farmland Exploitation and Food Production

The world's most populous nation, China's population growth, as well as supply and demand of food, have attracted considerable attention. Especially since 1996, several organizations concerned have issued pessimistic forecasts of the prospective supply-demand conditions in the country. If China falls into the position of the world's great grain-importer as forecasted, the global supply-demand food-balance will be destroyed.

1. Pessimistic Forecast of Supply-Demand Situation regarding Food in China

The forecasts by Mr. Lester Brown, Chairman of the US World Watch Research Center took the initiative in creating the pessimistic forecast trend. His research predicts that China will be importing about 200 billion to 300 billion tons of grains, which is equivalent to the world total grains currently traded, in the period between about 2020 and 2030. If this were to be the case, grain prices all over the world would soar and not only China but also the whole third world would suffer from starvation. However, Mr. Brown's forecasts are not sufficiently grounded. For example, a decrease in the planted area, which is one of the critical indices, is not expressed as any specific forecast value.

The Development Support Research Center of the Overseas Economic Cooperation Fund of Japan (OECF) also announced its forecast results in October 1995. They also expect a considerable amount of grain import by China, although their forecasts are 10% plus lower than Mr. Brown's. The Research Center's studies, however, also point out that the imports could be halved depending on China's efforts towards more domestic production.

2. Prospects for Population Growth, Farmland Exploitation, and Food Production in the 21st Century

Will China really become a gigantic grain importer, as forecasted by Mr. Brown?

According to the Chinese National Statistics Bureau, the total population in mainland China reached 1.2 billion on February 15, 1995. This is so large as to account for 21.4% of the world population, 5.7 billion. The bureau also announced that the future increase of the Chinese population would be controlled within 1.3 billion during the Ninth 5-year Plan period (1996 - 2000). In its long-term prospects up to the mid 21st century the total population of the mainland would be controlled within 1.5 or 1.6 billion, to eventually realize zero population growth. The population is expected to gradually decline after reaching its peak of 1.6 billion in 2030.

Such population growth has been attracting worldwide attention focusing on whether China will be able to support itself. In reality, China is feeding about 22% of the total world population with merely 7% of the total world farmland area. In the past 50 years since the foundation of the new China, its per-capita farmland area has decreased from 2.7 Mu to 1.2 Mu, due to population growth, while its per-capita demand for food has increased from 209kgs to 380kgs.

The Chinese Department of Agriculture and Ecological Environment Research Center of the Chinese Academy of Sciences has also announced their forecast results.

It estimates food production in China will increased by 72.1% between 1973 and 1995, and achieve 456.40 million ton in 1993, 460.00 million ton in 1995, and will achieve 500 to 520 million tons in 2000. In the meantime, the Macro Agriculture Research Center of the Chinese Agricultural Science forecasts that before 2020 when the population grows to 1.5 billion, the crop yields will increase to 670 million ton from 625 million ton, or to 450kgs from 425kgs per capita, so basically ensuring the self-sufficiency in food. Accordingly, the self-sufficiency rate of food in 2020 is expected to be 95%

or more, which is far above Mr. Brown's forecast of 41% in 2030.

In China current food imports account for only about 2% of the total domestic consumption. It is the country's consistent policy to be self-sufficient in food. Furthermore, the three major fundamental policies of family planning, environmental protection, and farmland protection are closely related to one another. Substantial farmland area in China has been occupied for the purpose of industrial constructions, etc. every year, but it is recouped by cultivating reserve farmland resources. For example, an average of 9.10 million Mu of existing farmland was lost each year from 1990 to 1993, whereas 7.02 million Mu of reserve farmland was newly cultivated annually. The result was only 2.08 million Mu of actual loss. According to statistics, China has 500 million (Mu) of wasteland which can be cultivated, and the Government is planning to cultivate an average of 5 million Mu each year from 1990 through 2000. Implementation of this cultivation plan is expected to add 200 Mu of new farmland to the current farmland area in the 40 years between 1990 and 2030. So, the "shortage of farmland" predicted by Mr. Brown will not occur as Mr. Brown predicted.

Agricultural Development Policy Based on Reinforcing Agricultural Scientific Technology, Increasing Agricultural Investments, and Specification of Total Development Districts

The trends in the 21st century is likely to be that the Chinese people's food consumption standard will improve, along with economic development and higher income levels, as direct food consumption per capita decreases while the proportions of animal-based foods, fruits, vegetables, vegetable oils, etc. increases remarkably, instead. In addition, progress in agricultural scientific technology is considered likely to greatly contribute to the increase in food production. While the substantial increase of food production in the former half of the 1980s was brought about by the collapse of the collective agricultural system and the subsequent establishment of individual management, further improvement of food production was achieved by technological progress. For example, hybrid rice, which China developed by itself, was planted in nearly 50% of paddy fields, attaining about 15 to 20% more productivity. The country presently obtains nearly 6,000 effective results in agricultural scientific technology research every year, and such technological progress is expected to increasingly contribute to the agriculture in future.

China specified the San Jiang Plain as the concentrated national agricultural development districts in 1988, and invested 700 million yuan in first-phase construction up to 1990. The second phase began in 1991, and the total investments up to 2000 are planned to amount to 3.4 billion yuan.

So far, 3.5km^2 of land has been exploited achieving 3.13 million ton of grain yields. While the development is carried on with the aid of loans from the World Bank, Japan, etc., various kinds of foreign-capital preferred policies have been introduced to promote the development further. Thus, this scheme aims to make rapid progress with a huge agricultural development project based on land improvement in the plain, and is considered to be very likely lead to multinational economic cooperation.

San Jiang Plain, as the total agricultural development district, has been divided into 306 development districts, where 326 development items have been carried out. These attempts have covered 69 counties, cities, and wards, and 96 farmlands (incl. pastures) and fishing grounds in Heilongjiang. Likewise, enormous agricultural development projects are going on in Jilin and Liaoning, too. The central government has already specified the San Jiang Plain, the Song Riao Plain, and the Riao He Plain as its focal areas for agricultural development, and expects to promote constructions of food production bases through large-scale investments.

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Table 1 Total Population and Increases of Productive-Age Population in three Northeast Provinces

Year	Total Population		Productive-Age Population	
	Population (0'000)	Year-on-year Increase (%)	Population (0'000)	Year-on-year Increase (%)
1953	4,357.3	—	2,279.3	—
1964	6,354.4	45.8	2,840.3	24.6
1982	9,129.2	43.7	5,272.6	85.7
1990	9,933.6	8.8	6,433.3	22.0

Source: 1) Statistical Yearbooks of Liaoning, Jilin, and Heilongjian Provinces, for 1991.
2) Materials of the 4th Population Census, 1992.

Table 2 Age Structure of Population in three Northeast Provinces

Age	Proportions to Productive-Age Population (%)
15～34	62.40
35～44	21.97
45～54	12.81
55～59	2.82

Table 3 Population by Industry in Three Northeast Provinces

Industry	Population (0'000)	Share (%)
Agriculture, Forestry, Stock Farming, and Fisheries	2,776.0	52.7
Manufacturing	1,268.8	24.1
Geological Exploration	10.7	0.2
Construction	165.4	3.1
Transport and Posts & Telecommunications	155.4	2.9
Commerce, Catering Service, Distribution, and Warehousing	355.8	6.8
Housing Management, Public Projects, Resident Services	83.6	1.6
Healthcare, Sports, Social Welfare	67.9	1.3
Education, Culture, Art, Broadcasting, TV-related	172.3	3.3
Scientific Research, Total Technological Service	17.9	0.3
Financial and Insurance institutions	28.9	0.5
National Organizations, Political Parties, Social Organizations	161.5	3.1
Others	5.5	0.1
Total	5,269.6	100.0

Source: Results of the 1990 Fourth Population Census.

Table 4 Future Population Estimates for three Northeast Provinces (1995 – 2000)

Unit: 0'000, %

Age	1996		2000		2005		2010	
	Population	Proportion	Population	Proportion	Population	Proportion	Population	Proportion
less than 15	2,443	23.4	2,422	22.2	2,253	20.0	2,098	18.2
15～49	6,294	60.2	6,467	59.3	6,454	57.3	6,300	54.8
50～59	799	7.6	940	8.6	1,337	11.9	1,659	14.4
more than 60	917	8.8	1,083	9.9	1,220	10.8	1,446	12.6
Total	10,453	100.0	10,912	100.0	11,264	100.0	11,503	100.0

Note: Author's estimates

Notes on Statistical Data:

a. Total Population: The 1990 population by sex and by year group was from the populations by sex of five age groups in the three provinces at the time of China's fourth population census.

b. Assumption on Birth Rate: For the 1990 birth rate, the 10% sampling results of the 4th population census, regarding the reproductive-aged female population's total fertility rate (TFR) in the three provinces were used as base.
The birth rates were 1.51 in Liaoning, 1.31 in Jilin, and 1.71 in Heilongjian. The 2010 birth rates are determined by annual average rates of TFRs of the reproductive-aged female populations in the three provinces. Accordingly, the 2010 TRFs of the reproductive-aged female populations in the three provinces of Liaoning, Jilin, and Heilongjian, are estimated to be 1.50, 1.60, and 1.51 respectively.

c. Assumption on Mortality Rate: The indices to express mortality rates used here are average life expectancies of the population groups at the time of birth. The 2010 by-sex average life expectancies in the three provinces are estimates, based on the by-sex life expectancies in the provinces in 1981.

The Agricultural Situation in China and Countermeasures

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1. Soil Enrichment and Expansion of Farmland

China is a large country of 9.6 million square kilometers in area, a large part of which, however, consists of mountains, cold wastelands, deserts, and arid or semi-arid areas. The arable land area is, therefore, relatively small, constituting only approximately 94.9 million hectares or 0.085 hectares per capita, equivalent to only a quarter of the world average level.

Arable land does not only provides a base for agricultural production, but is widely indispensable for constructions of cities, roads, factories, mines, etc. As the Chinese economy is in the midst of high economic growth, with its scale and the total volume of the economy continuously expanding, the uses of arable lands for non-agricultural purposes is creating very difficult problems. The farmland area in China has been decreasing by an average of 300,000 hectares every year, and the major cause is the use of the land for non-farming purposes. Since the population has increased while the farmlands have continued to decrease, the per-capita farmland area in China has considerably declined. The country had 98.5 million hectares of arable land, or 0.187 hectares per capita, in 1949, and arable area increased to 111.3 million hectares or 0.173 hectares per capita in 1957. In 1993, the area fell to 94.9 million hectares of arable land or 0.085 hectares per capita, a mere half of the 1949 level.

China's farmlands have not only declined in area but in quality as well. The organic content of the soil is already as low as 1% on average, which is far below those of farmlands in Europe and the United States, i.e., 2.5% to 4.0%. The Changjiang and the Huai Basins, which are important bases for agriculture, have less than 1% organic content generally, and in some places the rate is even 0.3% or less. The results of a sampling survey by the Province of Heilongjiang in 1989 showed that the organic contents of the soil in the northeast fertile soil zone, called "The Northern Granary", was 1 to 5%. It used to be 8 to 10% in the 1940s and 1950s. In addition, the farmlands have been constantly eroded by natural disasters such as alkalinization, desertification, or washing-away of soil. Currently, China has about 6.7 million hectares of farmland area exposed to the threat of alkalinization, plus nearly 4 million hectares at the risk of desertification. According to the latest result of a survey conducted with remote-detection technology by the sector concerned in 1992, the loss of the soil area was 3.69 million square kilometers, of which 1.794 million square kilometers was caused by water-erosion, and 1.876 million square kilometers by win-erosion. The amount of soil carried from the land of China to the coastal waters through the rivers amounts to 1,780 million tons. Adding accumulated mud and sand to this figure makes total erosion of over 5 billion tons.

Since 1949, the Chinese government has taken a series of measures to improve conditions of agricultural production, chiefly as follows. The measures: (1) improvement of the farming system by extending areas for intercropping, double or multiple cropping, and crop rotations; (2) aggressive development of farmland reclamation projects, by e.g., reclamation of about 35 million hectares of farmland in Heilongjian, Hainan, Xinjiang, Yunnan, etc. which have reclaimed about 650,000 hectares of farmland from the sea; construction of state-owned automated farms, which have become important bases for production of food, cotton, rubber and tropical economic crops; (3) powerful enrichment of the farmlands with low productivity, by construction about 6.5 million hectares of horizontally terraced farms, improving about 45 million hectares of alkaline lands, and conducting repairing work on about 4.5 million hectares of washed-away areas; (4) construction of drain and irrigation facilities, which increased the effective irrigable land area from 16.00 million hectares in 1949 to 493.65 million hectares in 1995, of which 322.10 million hectares benefit from mechanical and electrical drainage and irrigation.

Associated with population growth and developing construction of cities and villages, the contradiction of "more people" and "scarce rationally land" is becoming increasingly critical. Therefore, the Government values and utilizes every inch of land carefully and effectively as basic national policy, and intends to emphasize the following six points for a suitably long period of time. (1) Consistent observation of "The Land Law of The People's Republic of China", and implementation of methods to control the construction-use rate of land area, with non-use existing farmlands if possible, or to use as little area are as possible. Also, to reclaim the lands, again, where factories or mines were closed down. (2) Appropriate reclamation of wasteland and stabilization of the arable land area. China has approximately 35 million hectares of wastelands that will suit farming mostly north of the 35th parallel. They are most heavily distributed over the northeast regions, then Inner Mongolia and Xinjiang, and partly some southern provinces. It is inevitable that farmlands are occasionally exploited for other purposes, as urban and rural areas develop. In an attempt to maintain a stable farmland area, however, the nation has reclaimed wastelands appropriately to supplement the lands lost for construction of cities and villages in Heilongjiang, Xinjiang, Inner Mongolia, and some southern provinces or regions. (3) Implementation of intensive management of farming, and improvement of yields per unit area of existing farmlands. China has about 65 million hectares of low productivity farmlands, which accounts for two thirds of the total farmland area. To improve production of food and economic crops further, farmlands with low productivity must be enriched, and intensive cultivation and intensive management must be instituted. (4) Utilization of the tideland resources in the coastal areas for total development plans. Mainland China has 18,000 kilometers a coastline and as many as 2 million sq. hectares of tidal flats. As the middle region (consisting of 49 counties and cities mainly in Shanghai, Jiangsu, and Zhejiang) developed relatively early, it has attained comparatively a high reclamation level. That has helped the region make good economic progress through the planting of crops, cotton, rape-seed, sugar crops, mulberries, etc., the creation of salt pan, and farming of prawns, sea-tangle, squirting clams, etc. in freshwater. Thus, the region has been able to contribute its valuable experience in tideland resource exploitation to other areas. (5) Efficient maintenance of the soil, and protect farmlands in mountainous regions. 66% of the land area of China is mountainous and this contains a third of the country's farmlands. The greatest risk these farmlands are facing is the washing-away of soil. The country's restoration policy against this kind of damage aims to link the current benefit to the future benefit. It is thought that this can be done by establishing rational planning based on local natural conditions per small river-basin, carrying out large-scale, intensive and continuous flood-control works, taking biological and flood-control measures on a parallel basis, and linking the flood-control work with production. (6) Restoration of the northern areas under desertification, and protection of farmland in that region. In the northern regions of China, the desert has expanded by 32.8 million hectares, and some 4 million hectares of farmlands in 207 counties and cities in 12 provinces are at the risk of desertification. The restoration process of the land depends on the degree of desertification, and the climatic type. In the semi-humid areas with relatively good natural conditions, the restoration work is conducted to maintain the ecological balance by rational use of resources, and to help the lands affected by the desertification to restore their productivity. For the steppes in the semi-arid areas, the projects aim to reduce the amount of grazing on pasture, by artificial fostering of vegetation between hills or on lowlands based on the forest protection network, in addition to protecting the natural vegetation. As for the draught desert zones, the projects are designed to construct a forest protection system, disseminate water-saving or irrigation technologies, grow plants for sand-erosion prevention, and promote restoration of the ecological balance.

2. Forest Resources and Forestry Development

China's large land area, in which temperature and humidity vary greatly depending on the region, supplies a variety of ecological conditions required by diverse types of trees, which form rich forestry resources. The country has totally about 8,000 species of woody plants including 2,000 species of tall trees. Among the woody plants are some 1,000 species making good lumbers and special economic trees, and 6,000 species of shrubs. More than 50 species are tall species uniquely to China.

The results of the Fourth Forestry Resources Survey (1989 to 1993) show that China has 133.70 million hectares of forest area, accounting for 13.92% of the total land area, which is far below the world average of 22%. It has 11,780 million cubic meters of accumulated standing crops, and 10,137 million cubic meters of forest-nursery stock. Per-capita forest area in China is 0.11 hectares, which is merely a ninth of the world average. Lumber resource consumption of the country in 1993 was 320 million cubic meters, while the net growth increments of lumber were 400 million cubic meters, which is larger than consumption. Compared to the Third Forestry Resources Survey (1984 to 1988), however, accumulated mature lumber have decreased by about 200 million cubic meters, or an average loss of some 54.73 million cubic meters each year.

The problem is not only the scarce forest resources, but the irrational forest distribution and the tree-species structure in China. 9400 mm precipitation isohyet line runs from the western Daxing'anling area to the edge of Qing-Zang Plateau in the south, dividing the country between the southeast half favorable to growth of forests and the infavorable northwest half undesirable. The proportion of forest area is over 30% in many provinces in the east or the south of the country, including Heilongjian, Jilin, Zhejiang, Jiangxi, Fujiang, and Taiwan, while that in most provinces in the northwest region, including Gansu, Ningxia Hui, Xinjiang, and Qinghai, is less than 5%. In some areas it is even less than 1%. The main expression of the irrational forest structure in China is the large proportion of timber forests and the small proportion of windbreak and economic forests. A forest structure like this is undesirable for sustainable utilization of forest resources. In addition, China's utilization rate of the land area available for forestry is so low that only 45% of the area actually has forests. This fact denotes that the country has more than 100 million hectares of non-forest lands, which will allow potential development of forestation projects. The accumulated standing forest per hectare in China is 90 cubic meters, while the world average is 110 cubic meters and that in Switzerland is 234, which is the greatest in the world. The growth increments of lumber per hectare in China are 2.4 cubic meters, whereas that in the "forestry-developed" countries amounts to 3 cubic meters or more.

Since 1949, China has established forestry organizations on every administrative level from central to local, and implemented a series of policies, measures, laws and regulations to broadly promote afforestation which have achieved success to some extent. In the distant part, the country's the large land area was covered by many forests, which have been remorselessly destroyed by natural and man-made disasters over thousands of years. In the early 1950s, the forest area occupied only 8.6% of the country. From 1949 to today, coastal regions including Guangdong, Fujiang, and Zhejiang have created coastal protection forests, and provinces in the southern part of the Yangtze have timber and economic forests mainly consisting of cedars. Farmland-protection forests have been created in farmlands in the northern areas and the Yangtze midstream areas. Airplanes did seeding for creation of forests in mountainous areas of extensive breadth and small populations, where transport is not sufficiently available. In 1978, the Chinese Government began creating protective forests in the "Three Northern Districts" consisting of the Northeast, North, and West districts, and this afforestation project has been on the largest scale to date. With all these efforts, the proportion of China's forest area achieved 13.92%, with an artificially planted forest area of 33.31 million hectare, which is about a quarter of the country's total, the latter being the greatest total forest area of the world. The construction of nature reserve districts in China started in 1956. The project built up 763 nature reserve districts with a total area of 61,184,000 hectares, more than 90% of which belongs to forest nature reserve districts. This was quite meaningful in terms of protection of forest resources. The Government commenced the construction of a forest protection system in the forest districts in 1950, and has basically built up a forest fire-retardant system and a system to prevent disease and insect damage to forests.

The Chinese government is due to make efforts for the following projects which started in the late 1970s and will continue up to the middle of the next century. (1) Construction of two major bases of lumber and protective forests in the northeast and northwest districts. Although the northeast forest district is the country's largest base for lumber, the majority of the lumber has already been cut down by the many forestry bureaus, and the newly planted trees are not yet ready for cutting. The most urgent task is to implement renewal of the areas where cut-over has been completed, raise many trees, help new forest districts grow into the cut-over period, and a secure permanent forest production base in the northeast forestry district. On the other hand, the scale of cut-over is to be reduced in the forests of the southwest high-mountain district. At the same time, total utilization rate of lumber, i.e., lumber and residual products, will be improved, and multiple-species operation will be the main emphasis in the forestry industry. (2) Construction of bases for fast-growing lumber. Planted fast-growing trees grow rapidly, with a relatively short period to the cut-over time, and can be relatively quickly converted to lumber supplier. Therefore, developing the fast-growing lumber bases is one of the focal points of China's forest construction. Chinese provinces and districts to the south of the Qin Ling and the Dabie Mountains, including the southern Yangzi, Fujiang, Zhejiang, Hunan, Hubei, Guangdong, Guangxi Zhuang, Guizhou, Yunnan, Sichuan, Jiangsu, and Anhui, belong to the tropical belt, with mild climates and high precipitation, where trees grow relatively fast. The Government, therefore, has specified this extensive area as a base for its fast-growing lumber. (3) Completion of the "Three Northern Districts" protective forest systems in the mid- and up-stream Changjiang, Coastal, and Plain-farmland protective forest districts. The "Three Northern Districts" extend for 14,000 kilometers from east to west through the northwest, the north and the northeast regions, playing an important role in preventing desert expansion and washing-away of the yellow soil highlands. China has a total of more than 18,000 kilometers of coastline, with rich tideland resources, as well as many sandy lands, mountains, and hills. The Government also plans to establish coastal protective forest systems in those areas to reduce the loss caused by typhoons and prevent inundation of coastal farmlands and washing-away of soil from the coastal hills. The protective-forest system scheme for farmlands in plains has already involved 600 counties, or more than 40 million hectares of farmlands.

3. Freshwater Resources and Agricultural Irrigation

The total amount of water resources available for development in China is 2.8 trillion cubic meters (2,800 cubic kilometers), mainly consisting of surface water, groundwater, and glacial water. The total amount of surface water resources is over 2.71 trillion cubic meters (2,710 cubic kilometers), making 5.7% of the world total river flow. The groundwater and the total amount of water contained in the glaciers account for 825.2 billion cubic meters and 5 trillion cubic meters (5,000 cubic kilometers) respectively. These upstream sources together supply 55 billion cubic meters of water every year to major Asian rivers including the Changjiang, the Huang He (Yellow River), the Yarlung Zangbo, the Indus, and the Ganges.

As the geographical distribution of China's water resources is not well balanced, rainfalls and river flows diminishing gradually from the southeast to the northwest.

The time distribution of the resources is also unbalanced. This means that the distribution over a year shows imbalance and wide fluctuation. The seasonal distribution is such that the rivers in the southern provinces rise in the four months from May to August with 50 to 60% of annual rainfall, whereas those in the north rise in the four months from June to September with 70 to 80% of the annual rainfall. From the viewpoint of annual changes, there are great differences between the years with a high amount of precipitation and the years with a low amount. For example, in 1963 when the sea and rivers had high water content, the amount of water resource was as much as 53.3 billion cubic meters, which is 440% more than 9.9 billion cubic meters in 1972. Thus, the annual fluctuation is considerable, and tends to cause flood or drought damage, affecting agricultural production.

The distribution of water and land in China also lacks balance. The small amount of per-capita water resources is the greatest hindrance to the development of agricultural production. The area to the south of the Changjiang River has 70% of the national water resources, yet its farmland area accounts for only 31% of the national total. On the other hand, the area to the north of the river has 30% of the national water resources, but its farmland area amounts to 69% of the national total. Accordingly, the average water contents per hectare are substantially different from south to north. Those in Guangdong and Fujiang in the south are 90,000 cubic meters and 105,000 cubic meters respectively, while that in Hebei and Shanxi in the north is only 5,800 cubic meters. Even though the absolute quantity of China's water resources may not be small, its per-capita quantity is merely 2,700 cubic meters, equivalent to a quarter of the world average amount of water resource per capita. It is forecasted that the total demand for water in China in 2000 will be approximately 700 billion cubic meters, 80% of which is for agricultural irrigation. However, the amount of water resources available in a semi-drought year is 650 billion cubic meters, leaving a short-fall of 50 billion cubic meters. According to agricultural sector statistics, the shortage of water has forced the irrigation area or the effective frequency of irrigation to be decreased, causing a reduction of about 5 billion kilograms food production.

In the meantime, a considerable amount of industrial effluent and domestic sewage are discharged to pollute the surface and ground water. Statistics show that the total discharge of waste or polluted water in China was 33.6 billion ton in 1991. A 70% share of this amount belongs to industrial effluent, more than half of which does not meet discharge standards. The rest, 30% is domestic sewage, for which the proper disposal rate is less than even 10%. Of more than 1,200 rivers in the country, 850 have already been polluted, and all the seven major flows are contaminated at different levels. Such a further decrease of usable water resources has been dramatically increased the imbalance between demand for and supply of water.

The development and utilization of Chinese water resources has a long history, including the legend of the DaYu Riparian Works. The Dujiangyan Dam, built by those led by Li Bing and son in the year 251, is still functioning today. Again, the famous Great Canal was opened in 486. Ceaseless wars and diminished human capability of controlling nature resulted in frequent flood and drought damage. A history book records 1,500 breakdowns of dikes in 2,000 years to 1949 plus 26 major diversions of river courses.

From 1949 to the mid 1990s, China has carried out a number of water works, and made brilliant achievements in water-work constructions. To give some major examples, it constructed a total of nearly 200,000 kilometers of dikes and sea-banks, and 8,600 various kinds of dams. Most well-known are the Changjiang water-power stations at the Gezhouba Dam and the Huang He water-power station at the Longyangxia Valley. The total capacity of these dams amounts to 460 billion cubic meters, 80% of which is used for agricultural irrigation. In the northern arid areas, over 3 million electric-powered wells have been dug. These irrigation facilities provide the agricultural sector with 45 million cubic meters of water, making 49 million hectares of farmlands effective for irrigation. Among those farmlands, no less than a 32 million hectares endured drought and flood damage, and now ensures good harvests. Fundamentally, the country has brought under its control the Huang He, which used to flood frequently, and secured agricultural production and human lives in the basin from any breakdown of dikes since 1949.

To solve the problem of the supply-demand imbalance of water resources, the Chinese government aims to emphasize the following points, on the basis of a review of past experiences.

(1) A better grasp of the actual situation of water resources, taking appropriate measures on the basis of irrigation districts and planning, and conducting rational utilization and exploitation of water resources in a graduated and focused manner.

(2) Further increase of the number of facilities for irrigation works and carrying out of several major constructions for water storage. To solve the problem of unbalanced time distribution of water resources in the way, for example, that the well known Changjiang Sanxia project or the Huang He Xiaolangdi project did. Also, transfer of water from one basin to another. To solve the problem of uneven regional distribution of water resources by, for example, the "Water Transport from South to North" project, in which water from the Changjiang is transported to the Huang He. At the same time, reinforcement of the functions of existing irrigation facilities.

(3) Stress on water saving. To introduce state-of-the-art technologies, implement scientific and well-planned water utilization, and increase the utilization rate of water. In the past, it was often the case that only extension of the irrigation area was focused upon, and not much attention was paid to improvement of the utilization rate of water. This tendency caused substantial waste of water due to overflow or leakage at the time of irrigation of farmlands. Aggressively implemented at present is water-saving farming, a major part of which is diffusion of the irrigation technologies of sprinkler and instillation. These technological improvements can save water requirements of a half or two thirds of the amount conventional irrigation methods used to need.

(4) Establishment of a new ecological balance by growing grass, planting

trees, large-scale maintenance of water resources, and protection of the earth in the areas around water resources or the regions suffering from considerable washing-away of soil.

(5) To complete the relevant laws and regulations, and enhance control. In addition, to make efforts to guard water resources from pollution and wasteful use.

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Economic Planning and Population, Water Resources, and Food Production in China

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Economic Planning and Conditions of Population, Water Resources, and Food Production in China

Since its 'open-door' policy toward reform of 1978, the Chinese economy as well as Chinese society has made remarkable progress. The objective of increasing gross national product (GNP) fourfold by the year 2000 was attained ahead of schedule in 1995 through the three Five Year plans commencing from 1980. In 1996, the Government set forth " The Ninth Five Year Plan for National Economic and Social Development, and Outline of Long Term Objectives towards 2010", to set new goals. It aims to control the population within 1.3 billion until 2000, quadruple the 1980 per-capita GNP by 2000, and double the 2000 GNP in 2010 while holding the population within 1.4 billion. If these objectives are accomplished, the country's social productivity, total national strength and the people's living standards will all considerably improve, and the base for the goal of virtually completing modernization in the mid 21st century will be firmly established. These objectives are attainable, yet involve a number of problems, since various economic and social factors will have more or less impact on the attainment of them, either favorably or unfavorably. Analyses of those factors and proposal of necessary measures will play important roles in leading the country toward smooth accomplishment of its objectives. There is no room for doubt that population, water resources and food production are the key factors to modernization of China.

1. Economic Development and Food Production

As Chinese agriculture has been built on a weak base, it is not sufficiently responsive to the demands of population growth, improvement of living standards, and economic development. Sustainable and steady development of agriculture and rural economies is, therefore, a very important but most difficult issue in China's economic development. Nonetheless, its food production has shown a remarkably stable improvement in the process of the country's economic growth.

When the new China was founded in 1949, the national food production was 113.2 billion kilograms or 209kgs per capita. In 1978 the respective figures were already 304.8 billion kilograms or 317kgs per capita.

As a result of a series of reforms of the agricultural system based on the household-based contracting production started in 1978, national food production increased to 350 billion kilograms, 400 billion kilograms, then to 450 billion kilograms. It reached 456.4 billion kilograms in 1993, the world greatest, with the per-capita production, 387kgs, at the world average level. Further, the national food production in 1997 was as high as 492.5 billion kilograms. In other words, China is feeding 22% of the world's population with 7% of the world farmland. The target food production level in the Ninth Five Year Plan (1996 to 2000) is to achieve 490 to 500 billion kilograms in 2000. The trend of the country's food production implies continuous growth in the long term.

Looking from the perspective of the historical experiences of China's economic development, when the national economy was rapidly growing, agriculture, especially food production, often tended to increase rather slowly, while, conversely, the latter often expanded speedily when economic development was sluggish. The Chinese economy is likely to maintain quite a high growth rate over the next ten years. "The Ninth Five Year Plan and The Outline of Long Term Objectives Towards 2010" aims at a growth rate of GNP at annual averages of 8% in the ninth five-year period, and 7% in the first ten years of the 21st century. A number of observations and research results forecast that the country's actual economic growth rate in the next ten years or more will be around 9%, exceeding those target figures. This forecast value is far above the world average level. While food production has continued to grow in the 1990s due to rapid economic development, the annual average rate of increase in crop yields has slightly declined. There is concern that this might represent a long-term trend. But it does not, for the following reasons.

(1) The Government places a great emphasis on protection of domestic food production in its policies regarding production, imports and exports. This can be understood from the report "Food Problems in China" issued by the Government.

(2) Domestic farm products and especially the food market system will continue to be improved by reforms, so that they will more powerfully promote increases in production of price-elastic foods.

(3) Chinese food production still has substantial potential power for growth. The potential power will become real should the necessary conditions regarding capital, technology, labor input, government policies, and systems be satisfied.

Many experts and researches by national research organizations (e.g., Lin Yifu, 1995; Li Yueyun, 1996) maintain that improvement in productivity per unit area, as a major factor, will make possible an increase in China's food production, on condition that food production policies and changes of system (e.g., to contracted operations) are basically stable. According to the June 1996 survey of the land-utilization situation nationwide, the country's farmland area actually used is 133 million hectares. This gives about 3,000kgs per hectare of Chinese food production, which is far behind the production level in agriculturally-developed countries. There are also considerable differences in yields per unit area between the various provinces of the country, denoting the potential for further improvement. To improve unit-area productivity, China has taken the following measures: (1) increase of irrigation works; (2) improvement of multiple-cropping indices; (3) enrichment of low-productivity farmlands; and (4), progress in agricultural science and technology.

Two thirds of the existing farmland area in China is of low productivity, production per hectare being 2 to 3 tons lower than that in high-productivity farmlands under the same climatic conditions. The Government plans a total of 32 million hectares (14 million hectares of which come within the Ninth Five Year Plan period) of enrichment of farmlands nationwide in the ten or more years to the early 21st century. Based on the experience of Henan Province, a hectare of farmland enrichment is estimated to bring about a 1,000 to 1,500kgs increment, thus, nationwide enrichment is to produce additional 32 to 48 billion kilograms of food. More importantly, the agricultural science and technology as well as improvement of unit-area productivity will raise the possibility of increase in food production. The 1997 summer crop yields marked a record high, a 10,750 million kilogram increase, as a result of a great improvement in unit-area productivity, thanks to increased input of scientific technology and good climatic conditions. Of the total increase in production, 95% was brought by the improved unit-area productivity ("Economic Daily", July 31, 1997). Therefore, further attempts to increase the unit-area food production are considered capable of keeping the country's food production growing in the 21st century.

The annual average rate of increase in food production in China between 1952 and 1992 was 2.52%, while that between 1978 and 1984 was as high as 5.35% and that between 1978 and 1992 3.04%. If we assume that food production increases at the 1978-1984 rate, total production will reach 671.7 billion kilograms. If it increases at the 1978-1992 rate, total production would account for 562.5 billion kilograms in 2000. If we further assume that it increased at the 1952-1992 rate, then total food production would be 549.9 billion kilograms in 2000. Likewise, even at a relatively low rate of increase, no problem is likely in attaining the food production target-level of the Ninth Five Year Plan.

2. Agricultural Policy and Water Resources

Chinese agricultural policies have consistently aimed at stable growth of production of basic agricultural products, especially foods. The measure taken to secure stable increase in food production is expansion of the irrigated area of farmlands. Not even half the farmland area of China has so far been irrigated, but that irrigated area accounts for two-thirds of national food production. The irrigated farmland area in China is the largest in the world, and the demand for agricultural water is extremely high. However the expansion of irrigated farmland area is constrained by shortage of water resources, which is a critical constraint on sustainable and stable growth of food production. Per-capita water resources in China are merely a quarter of the world average level, and the average amount of irrigation water for farmlands also is only half of the world average. In other words, the water shortage situation in the country is extremely severe. In addition to insufficient water-resources, China also possesses the following features.

(1) Agricultural demand for water is considerable. Of 476.7 billion cubic meters of national water resource per year, 419.5 billion cubic meters or 88% is used for agriculture, mainly for irrigation purposes.

(2) Regional distribution of water is quite uneven – much in the south and a little in the north. The areas to the south of the Changjiang River have some 70% of national water resources, but only 31% of national farmland area. Those to the north of the river, on the other hand, possess about 30% of the national water resources, but as much as 69% of the national farmland area. The water resource per capita contained in the south- west region amounts to as much as 38,400 cubic meters, fifteen times the national average, whereas average per capita and farmland water-resources in the vast northern regions with their high populations are much lower, with as little as 430 cubic meters per capita in some areas.

(3) Seasonal and annual changes in rainfalls are extraordinarily great, frequently causing flood and drought damage. The highest annual precipitation is two to four times the lowest in the southern regions. The highest in the north is three to six times the lowest in those regions.

Most parts of the country have approximately 70% of annual rainfall in a maximum of four months. The rate exceeds 80% in the northern plains. These characteristics, marked by considerable annual changes in and seasonal high concentrations of precipitation, have caused a number of large-scale droughts and floods. These are major factors in the instability of Chinese agricultural production. Therefore, construction of irrigation facilities to cope with droughts and floods is one of the great critical objectives the country's agricultural sector must attain.

(4) The effective utilization rate of water resources is relatively low. The effective utilization rate of irrigation water in farmlands is about 40 to 65%.

Water is the major problem impeding agricultural development in China in the 21st century. Confronted with this problem, the country's agricultural policies for the next century emphasize the following measures. The first measure is aimed at reinforcing irrigation-related construction. Large- or medium-scale irrigation projects to go beyond this century will mainly consist of irrigation works at rivers and lakes. This measure includes constructions in the Changjiang Sanxia Project, the Huang He Xiaolangdi Project, and the Sichuan Ertan Project to improve the capability of coping with floods and droughts. Once in place, these works will significantly enhance the ability, needed in agricultural production, to withstand natural disasters and to overcome the shortage of agricultural water in the 21st century. The second measure will build up basic agricultural facilities for the expansion of the irrigated area, focusing on irrigation for farmlands. Irrigation systems will be introduced to improve production conditions, aiming at an upsurge in agricultural production. The third measure is directed towards wide diffusion of water-saving irrigation technologies. On the basis of an estimate of roughly 450 billion cubic meters of national agricultural water resource, a 10% increase in the effective utilization rate of water could supply an additional 45 billion cubic meters of water per year, equivalent to the construction of dozens or even over a hundred large dams.

The introduction of these measures will benefit China's agricultural development and secure increases in food production, and also alleviate the problem of water-resource shortage.

3. Population Growth and Food Production

The huge population is the most fundamental fact of China, and the population problem has long been and will continue to be the key issue in the country's modernization process. According to the fourth population census in China, the total population in the Mainland reached 1,133.68 million in 1990. It had exceeded the 1.2 billion mark already in 1995, accounting for 21.4% of world population.

Chinese population statistics, issued by departments concerned, show that the population will tend to grow gently between 1995 and 2010, and continue to do so for quite a long time before eventually attaining zero growth. Those years will be the vital period for China in achieving its population- goal. The Government set forth the objectives of keeping the population within 1.3 billion until 2000, and within1.4 billion until 2010. This implies that during the first ten years of the 21st century, another 200 million will be added to the 1.2 billion of the 1995 figure.

Thanks to the successful implementation of planned childbirth, the birth rate in China has already declined to the replacement level. Due to the inertia of population growth, however, some 13 million have been newly added every year on average. According to United Nations projections, even at such a low birth rate level, the population will continue to grow until the 2030s when the Chinese population is likely to amount to about 1.6 billion. Also, it must be noted that the current birth rate involves substantial regional differences, and is quite unstable. In view of the uneven regional distribution and instability of the birth rates, it is very likely that the population in the future will exceed 1.7 billion, or even 1.8 billion, should the birth rate show a rebound. The demand for food in the 21st century created by the immense scale of the population and its continuous growth will bring massive pressure to bear on Chinese food production. Crop yields have been continuously increasing, yet most of the increments have been consumed by the additional population.

Furthermore, due to the decrease in the available land area stemming from the population growth and economic development, the per-capita arable land area in China decreased from 0.18 hectare soon after the establishment of the modern nation to 0.11 in 1996. Especially, economic growth and the increasing population density in the Changjiang and Zhu Deltas is gradually converting the arable land that is most suitable for food production to other uses, seriously affecting production and supply of food.

As China is going through a high economic-growth period, solution of the food problem will be an important issue in the modernization process in future. China is a country with an immense population. Nations or regions with small populations may be able to solve food problems by imports, but such is not the case for populous countries. Total world food production is sufficient to meet the demand of the total world population now, yet a number of countries and regions are suffering from shortage of food. China needs steadily to maintain self-reliance with regard to food-supply as well as its high self-sufficiency rate, and that is the foundation which will guarantee sustainable growth. As a matter of fact, China has always been on this track.

To meet the huge population's demand for food, Chinese agriculture has no choice but to pursue long-term maximization of food production. However, as production has increased, the law of diminishing marginal returns has come into play, and the consumption rate of farm products especially crops has increased continuously– from 30% in 1984 to 35.6% in 1992, then to 42.5% in 1993. This trend sharply increases the marginal cost of food production. For the moment, China's domestic food prices are at the same level as those of the international market. Such continuous increases in food prices imply that China will have to introduce, as a developing nation, the agricultural protective policies which only developed countries can normally adopt. This tendency may transfer resources from the industrial sector to the agricultural, hampering industrial progress.

The population growth rate in China is not necessarily high in comparison with many other nations. Nonetheless, the country must maintain the planned childbirth policy for the control of population growth, aiming for zero growth, while under the constraints on food production mentioned above. Such maintenance will have a direct impact not only on China's development itself, but also on the future population of the world, will influence the world resource environment and socio-economic cooperative development, and will affect whether or not the human race can get on track for sustainable development.

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Chapter 3

Population in India
- Politics and Trends -

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1. Population Transition in India

The Indian population in 1998 (middle of the year) was estimated to be 987 million and will likely exceed 1 billion in a year or two. As is well known, India is the world's second most populous nation, second only to China (population 1.26 billion), and with a population density of 285 per square kilometer it has, together with Bangladesh, the higher level among the major developing countries. The country is also known for its planned parenthood policy, India having been the first country in the world to introduce such as national policy, in its initial 5-year plan starting 1951, although the growth rate of its population is still as high as 1.8%, and an annual increase is over 17 million heads per year, which is the largest number in the world, easily exceeding that of China. Such population growth has imposed great burdens on the development of India, especially on the securing food production and water resources. This chapter will consider India's future population trends by reviewing its distinctive demographic features and investigating their causes.

India freed itself from British colonialism and won its independence after separating from Pakistan in 1947. The population growth of the country since then has been substantial. India's first population census after its independence, conducted in 1951, showed that the total Indian population (excepting Jammu and Kashmir where the census was impracticable due to the border dispute) was 357 million. It increased some 130% to 838.58 million (about 844 million including the estimated population in Jammu and Kashmir) over the next forty years to 1991. The average rate of population growth for the period is 2.1% per annum.

According to the United Nation's estimates of future population, which are prepared based on observations of the demographic trends up to recent years, the Indian population is expected to increase rapidly and to exceed 1.2 billion by about 2010, 1.4 billion about 2025, and 1.6 billion around 2040.

The forecast of annual increase is above 15 million until around 2015, and is expected to fall to 10 million in the latter half of the 2030s.

The distinctive features of population transition in India become more obvious when compared to those in China.

The current rate of increase (1995-2000) is 1.8% in India, much higher than the 1.0% in China, and the gap between the two is unlikely to be greatly narrowed in the future. Even in 2020-25, a quarter of century further on, the growth rate in India is expected to remain as high as 1.0%, being double that of China, which is expected to be 0.5%. As a result, while population growth in China is expected to rapidly slow down, in India rapid growth will continue. According to the UN's estimates (medium), the two countries swap ranks in 2045, or near the middle of the next century, and India will be the No.1 population giant. (See Tables 1 and 2)

This difference in population growth between China and India became more evident from the latter half of the 1970s. India's population growth rate remained kept as high as 2% or above until the latter half of the 1980s. The notable and constant declining trend began to be observed only in the latter half of the 1980s. In China, on the other hand, the population growth rate has shown unusual changes ever since the establishment of the People's Republic of China in 1949. Following the baby boom right after the founding of the Republic, the growth rate dropped to 1.5% in the latter half of 1950s. It then started to rise, exceeded 2% in the period between 1960 and 1975, viz., from the Great Leap Forward to the Great Proletarian Cultural Revolution, and reached 2.6%, far above the growth-rate in India, in the latter half of 1960s. In the latter half of the 1970s, however, China's population growth fell drastically to 1.5%, and has since continued to decline while maintaining the difference (in rates) with India's growth rate. (See Figure 3)

Thus, in contact with China, India's population is expected to continue its rapid growth. In view of the critical role played by population growth in the country's social and economic problems, it is important to carefully consider the factors which will affect its future population, and the conditions which influence them, so to avoid making the wrong decisions when setting policy.

2. Factors in Population Growth

<Mortality Transition >

Since its foundation, India has steadily reduced its mortality rate by improving the population's nutrition, public hygiene, medical services, etc.

The annual mortality rate was 25 per 1000 in early 1950s, but has been greatly improved to about nine today. The average life-expectancy which was below 40 right after independence, is also about to exceed 62 years now, and infant mortality has dropped from 190 per 1,000 to 72 during the same period, showing a decrease of more than 60%.

The decline in the mortality rate in India, however, roles in comparison with the dramatic changes in China. The mortality rate of India was 25 per 1,000 in the early 1950s, the same as the former, but it had dropped below 7 in the early 1970s, 20 years on. In the same period, China's infant mortality rate fell from 195 to 61, and the average life expectancy rose from 39 years to 62.5 years. Progress which took India 50 years to achieve, was made in only 20 years in China. The substantial gap between the two countries cannot simply be explained by the differences in development of medical technology or its diffusion among the people, but is owed to the fact that education and reform of social structure spread thoroughly throughout China, including its rural communities. Conversely, the gap in improvement in the mortality rates represents India's relative lateness in social modernization, and it is important to recognize this fact when contemplating country's future prospects.

<Fertility Transition>

Any decrease in the mortality rate accelerates population growth unless associated with a decrease in birth rate. The reason the Indian population growth rate maintained a constant level of around 2.3% starting in the 1950s to the first half of the 1970s, despite the fall in the mortality rate, should be explained by the gradual decline in its birth rate. The total birth rate in India was 6.0 in the first half of the 1950s, which dropped to 5.4 in the first half of the 1970, and the rate of decline of the birth rate accelerated in the latter half of 1970s. The total birth rate declined by 0.54 percentile points during the 20 years from the first half of the 1950s to the first half of 1970s, but by 1.68 points in the following 20 years from the first half of 1970s to the first half of 1990s. The rate of decline was more than triple.

It is, however, quite hard to find any social or economic factors for the acceleration in the birth rate's decline in the latter half of the 1970s. At that time, India was suffering from political and economic problems, including famines caused by the abnormal weather, as well as the inflation stemming from the oil shock.

The second Indira Gandhi administration attempted to overcome such difficulties by applying stronger regulatory policies, among which was enforced family planing involving sterilization at its core. Thus, this policy is considered the only factor accelerating the decline of the birth rate during this period. The coercive nature of the operations, however, is said to have provoked the people's fury and became a factor in the severe defeat suffered by the All-India National Congress Party in the following general election.

Population trends cannot be easily manipulated by the government policies alone. Especially, when it comes to the birth rate, family planning cannot achieve any desired effect unless a large-scale demand for fewer children exists among the general public. Even if birth rate decline is temporarily achieved, it is difficult to maintain or build on without such popular demand. There is an argument that attributes the delay in India's family planning to bureaucratic inefficiency or to the political system lacking organizational force, but I do not think they explain everything. It is very important to grasp this point correctly in considering the future of India.

3. Regional Gaps in Demographic Transition

In India, the trend towards decreasing population is especially conspicuous in Kerala at the southern extremity of the country. The total fertility rate in 1991 in Kerala was 1.8 which was much below the population replacement level (2.05), and almost equivalent to those of developed countries in Europe, the United States, and Japan. Next to Kerala is Tamil Nadu at the southeastern tip, where the total fertility rate was 2.2 in 1991, which approaches the level of population replacement. Other than these two regions, the decline in the birth rate continues below the national average of 3.6 in Karnataka (3.1), Andhra Pradesh (3.0) in the southern area, as well as in Maharashtra (3.0), Gujarat (3.1), and West Bengal (3.2) in the mid-east area. (Union territories and smaller states are not included in the comparison.)

On the other hand, the fertility rate of India, as a whole, is raised up by the five regions in the so-called Hindi belt that contains 42% of the national population; namely, Bihar, Haryana, Madhya Pradesh, Rajasthan, and Uttar Pradesh. The birth rates in these regions are extremely high; their total fertility rates were all above 4.0 in 1991. This includes 5.1 of Uttar Pradesh which is 180% higher than that of Kerala.

The gap between the two widened compared to 1981 where the total fertility rate of Uttar Pradesh (6.1) was 110% more than that of Kerala (2.9). While the fertility rate of the country as a whole is observed to decline, the southern areas are rather more advanced in lowering the rate, and the northern areas are behind them. The gap between the southern, middle and eastern regions and northern regions has tended to become wider after 1991 as well.

What has created such a wide regional gap in fertility rates in the same country? It cannot be explained by economic disparities or different paces of urbanization, as generally presumed. The first thing to draw attention to is that the northern states with high birth rates are all in the so-called Hindi belt, where the population speaking Hindi as mother tongue exceeds 80% of the total, which makes a clear difference from the other regions. According to the 1991 census, other states with the higher Hindi-speaking populations are Punjab (15%) followed by Maharashtra (7%). The difference in languages alone cannot be a factor in impeding the lowering of the birth rate. More intrinsic causes ought to be behind it.

We have sampled various social, economic and political factors out of statistical data mainly based on the 1991 population census, and calculated their correlation coefficients against fertility levels. The results showed no significant correlation between fertility levels and any of the following; each state's average income, urban population ratio, industrialization level, ratio of specific caste, the government's per-capita budget for family planning, or density of doctors/hospitals, etc. On the other hand, some important factors have emerged as follows.

First, the higher negative correlation coefficient was observed between the ratios of employed workers to the total work force ("employees ratio" hereafter) and the fertility rates. Employees in India exist not only in the commercial and industrial sectors in cities, but also very numerously in the rural areas as landless agricultural laborers. The latter account for 40.3% of total agricultural workers, and 23.7% of total workers. By adding the 28 million marginal workers (casual laborers who work at various workplaces depending on seasonal demand) that make 9.0% of total workers, and also most of the non-agricultural and non-forestry workers (whose employment status is unknown), the ratio of the total employees to the total work force will be around 40%.

There are large differences in this ratio from state to state, but such employees-ratios have the higher correlation coefficient against the total fertility rates in each state. The second important factor is female literacy. Literacy rates were obtained separately for men and women. While both rates are correlated significantly with fertility rates, that for women has a higher correlation coefficient. The third higher coefficient against the fertility rates belongs to the infant mortality rates, and the fourth greatest to the rates of the "protected" couples. Protected couples are those whose pregnancy risks are effectively protected by government family planning.

Since social and economic factors, including those mentioned above, are mutually and complexly related to one another, it can be misleading to make conclusions on the basis of simple correlation coefficients alone. Therefore, we applied statistical processing, and replaced the data with regression equations to calculate standard partial regression coefficients. The result obtained shows that the overwhelmingly influential variable is the employee-ratio, and that significant but much weaker variables are the rates of female literacy and protected couples.

	Simple correlation coefficient against total fertility rate	Standard partial regression coefficient against total fertility rate
Rate of wage workers	–0.92	–0.81
Rate of women's literacy	–0.80	–0.10
Infant mortality rate	–0.77	–
Rate of protected couples	–0.57	–0.04

To sum up, the regions leading the decline in fertility rates in India have high rates of wage workers, including non-agricultural/forestry workers and landless agricultural workers in the rural areas. In other words fertility decline is slower in the regions with relatively many traditional farmers owning lands. In view of the regional variations, it is observable that the modernization of employment relationships mainly in the rural areas is the basic driving force toward the declining birth rates. Although it is true that educational investment to improved female literacy and government family planning have lowered the birth rates to some extent, it can be considered that the prerequisite for success is that the benefit of small families is recognized among the general public as the result of the modernization of employment relationships.

4. The Future Population of India

India's population transition is rather slow, relative to that of China. Since both countries have high proportions in the agricultural sectors, the speed of population transition depends on the modernization in rural communities. India's agrarian land reform after independence was insufficient and the social structure in agricultural areas in the colonial period has been handed over as it was. Unless an appropriate improvement is made in this issue, it will be difficult to accelerate the transition of population of the country.

According to the low variant of the United Nation's future estimates, on the assumption of rapid population transition, show that the population growth rate will decline at an increasingly faster pace in the 21st century, and that growth will hit a ceiling in 2040 when the total population of India will be around 13.5 billion. This is 250 million (16%) less than the aforementioned medium variant estimate of 1.6 billion. On the other hand, if the population transition were to be hindered due to delay in social and economic modernization, the country's population could even reach 2 billion in the mid 21st century (by high-variant estimates).

Future populations are not fixed figures and can vary depending on social or economic modernization, government policies on education or family planning. Nonetheless, securing a base to support the increasing population should be the foremost crucial issue for the future India. If the country does not succeed in maintaining the constant decrease in the mortality rate, especially by securing water resources and promoting food production, all the estimates of future population will lose their validity and completely different scenarios will emerge.

Figure 1 Population Trends: India vs. China

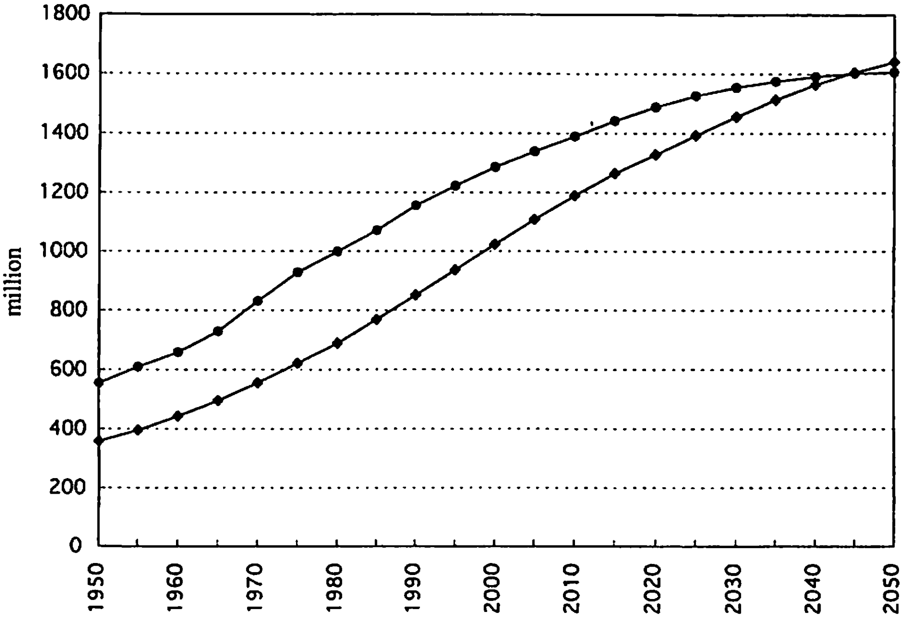


Figure 2 Annual Increase in Population: India vs. China

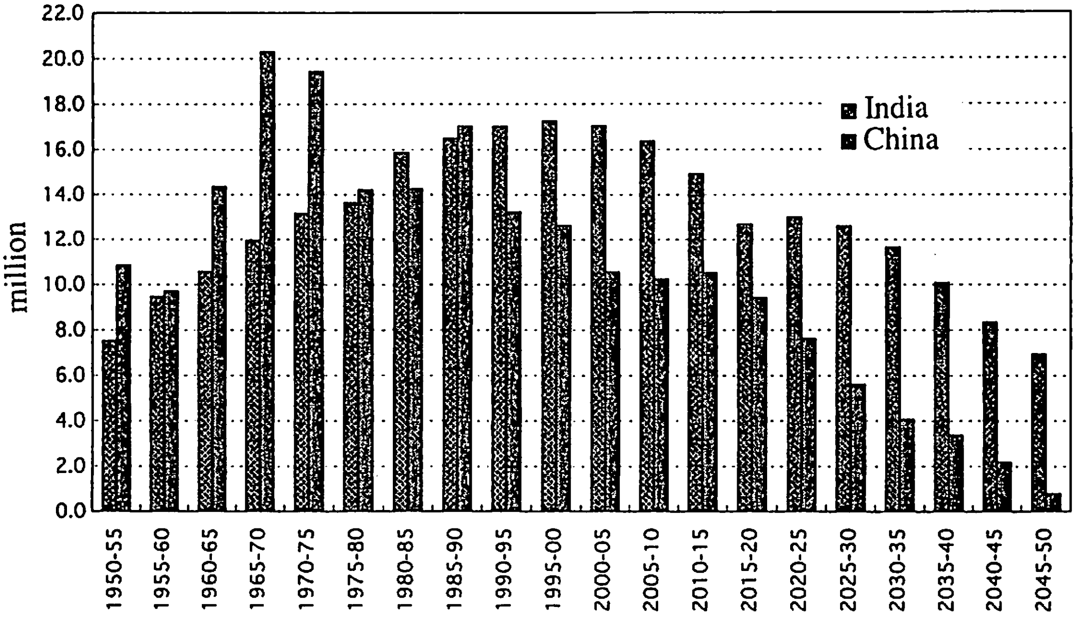
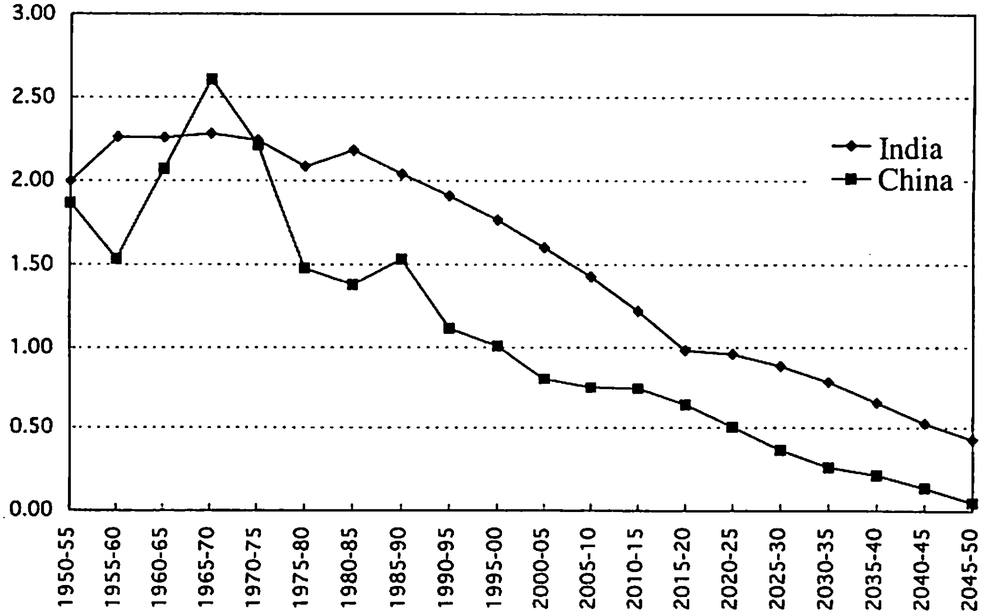


Figure 3 Trends of Population Growth Rate: India vs. China



Constraints on Growth and Strategies for 21st Century with Regard to Population, Water Resources, and Food Production

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1. Economic Development and Agriculture

1-1 "Population and Agriculture" and Economic Development

The population of India rapidly expanded from 363 million in 1951 to 932 million in 1996, with the scale of the increase in a 10-year period during the '70s and '80s exceeding the population of Japan (125 million, estimated in 1995). How to cater for these people is an important issue for the management of the economy. On the issue of "population and food", however, it is insufficient to discuss only the relationship between the two. The issue must be considered within the paradigm that involves the mutual impact between itself, and economic development. Especially in India, the issue is closely related to resource mobilization of development funds, and therefore, significantly affects the progress of economic development.

Resource mobilization of funds for development is a crucial political objective for developing countries in order to achieve economic take-off. The newly industrializing economies (NIES) and Southeast Asian countries employ strategies of relying on foreign capital in forms of direct investments and/or loans, whereas China mobilized resources domestically through exploiting agricultural. India, however, has not applied the Chinese style of resource mobilization, though India attempted to take the same heavy-industry oriented path. This was because agricultural production activity. in India is left dependent on the market. Looked at from a different viewpoint, while China established a capital accumulation mechanism in the early stage of economic development through political reforms of ownership structures, as represented by the people's communes and state-owned enterprises, India has not made sufficient reform on the land ownership system, leaving the ownership structure almost unchanged since those days before its independence. Part of the reason agricultural exploitation, as employed in China, was avoided in India is that one of the major components of the Congress, which had long been the ruling party, was the wealthy farming class known as Zamindar. In fact, the combined proportion of the agricultural land tax and the agricultural income tax in central and state government revenues rapidly declined from 7% in the 1960s, reaching about 2% in the 1970s, and further dropped to below 1% in the 1980s.

Due to the bitter experience under colonialism, India also rejected direct investment from abroad. Industrialization strategy under such circumstances brought severe budget constraints on the country's development strategies. Those constraints consist of external restrictions on foreign-reserves and internal restrictions on budget. As a result, serious problems occurred due to the former during the period following the independence, and serious problems have occurred due to the latter up till now. Deeply involved in those problems is the agricultural policy the Government employed to feed the expanding population.

1-2 Scarce Development Funds

Increased import of capital goods to implement import-substitution industrialization forces the national economy to the limits in balancing international payments, as we experienced in Japan in the 1960s. India applied a policy that prefers heavy industry, in particular to substitute for imports, not to foster the export industries. Consequently, in India with a few established export industries, the increase in imports of capital goods induced by the import-substitution industrialization further pushed up the trade deficit, and depleted foreign currencies in no time. This can be observed from the fact, for example, that the ratio of trade deficit to GNP (Figure 1-1) was at a peak in 1957, and at the same time, the ratio of foreign exchange reserves to imports (Figure 1-2), which used to be above one, sharply dropped. Thereafter the trade deficit-GNP ratio remained high, and led to the economic crisis of the mid-60s, to be mentioned later. Internally, on the other hand, the budget deficit deteriorated in-hand with progress of the 5-year Plan. Government expenditure, that is not fed by ordinary annual revenue, is paid for by foreign and domestic capital borrowings including loans and donations. Remaining budget deficit is then recouped by additional issue of money which is not backed by the real economy. Table 1-1 shows the ratios of borrowings to the total budget of the 5-year Plan in its early stage and the rates of budget deficits, in which the vulnerability of India's fiscal base can be seen. However, this problem became visibly crucial only in the 1980s.

1-3 Ricardian Growth Trap and Advent of the Agricultural Crisis

Let us review the status of India, having difficulties in procuring development funds, in relation to its agriculture. One of major conditions of progress for an economy such as India holding a vast surplus labor would be that its industrial sector continues receiving benefits from the Lewisian type unlimited supply of labor for the longest time possible. However, despite the existence of surplus labor, real wages may increase and restrict the growth of the industrial sector.

This is because, in a low-income economy with a high ratio of food cost to the total spending, as price of food increases, wages also increase to sustain lives of factory laborers. As a result, the wages become a constraint that push down the profits of the industrial sector, impeding industrialization – the theory known as Ricardian Growth Trap said to apply to the British economy during the period of the Industrial Revolution (Figure 1-3).

Western European countries received cheap food supplies from the New World, and Japan acquired paddy from the colonized Korean Peninsula and Taiwan in the process of their economic development, so to get out of the Growth Trap. Today's developing countries, however, cannot expect such solutions. If they attempted to restore balance between supply and demand by importing food, it would then reduce the foreign exchange reserves sacrificing imports of the capital goods or technologies that are essential for their import-substitution industrialization. Industrialization would go into impasse as a result. Let us call such stagnation of industrialization by foreign currency constraint the "external trap" to distinguish it from the "internal trap" which is caused by the wage constraint. This classification provides effective viewpoints from which to consider the agricultural sector's potential impact on the industrial sector of when the excess-labor economy attempts to take-off.

Since immediately after its independence, India has suffered from chronic food problems caused by rapid population growth. The terms of trade between agriculture and industry (Figure 1-4) only made the country's agriculture deteriorate rather than bringing about any advantage, until the food situation came to a crisis due to the two consecutive years of droughts in the mid 1960s. This was because a cheap food supply was required by industrialization during this period with the second and third phases of the 5-year Plan giving top priority to the industrial sector. This made imports supplement the food shortage. The per-capita daily foodgrain consumption (including pulses) was 450.45 grams (Standard Deviation = 19.74), on average for ten years until the agricultural crisis occurred in the fiscal year 1965, which was almost at the same level as the average of 458.65 grams (SD = 24.90) for the period from fiscal 1967 to fiscal 1994. However the consumption level up to the mid 1960s was attained not only by domestic supply but also by a great deal of imports of foodgrains including food aid. Imports of foodgrains were already full scale in the latter half 1950s, and the ratio of foodgrain imports to the total imports has always been above 10% since the 1960s. This meant a placing of tighter foreign-currency constraints on industrialization. At the time of the agricultural crisis in the fiscal 1966, foodgrains occupied 31.3% of the total imports. The amount of imported rice accounted for less than 10% of the total amount marketed domestically, whereas that of wheat exceeded 100% of the total wheat marketed domestically, and reached 230% in 1966. These figures demonstrate the scale of impact on the domestic foodgrain supply –demand balance of the import of foodgrains.

This implies that the conditions of the country's economic crisis in the mid 1960s were prepared in the late 1950s where import of food was restricting the amount of foreign currencies. Consequently, the foreign-currency crisis induced by the agricultural crisis destroyed the economy. This means that India fell into the external trap of tighter foreign-currency restrictions caused by the foodgrain import.

The reason that India fell into the external trap, rather than the internal trap, lies in the Indian doctrine which primarily focuses on stabilizing food prices. For a country that has not conducted any reform of the notably unequal private ownership structure, poverty is the most serious political issue. Poverty in India is quantified by the concept of the "poverty line". The poverty line is defined as the expenditure that can cater for the daily energy intake required for maintaining life (2,400 calories per adult man in rural areas, and 2,100 calories in urban areas); households with expenditure under this level are referred to as the poverty class. The proportion of the poverty level was 55.2% in the fiscal 1960s, and 37.4% even in the fiscal 1983, implying that the Indian economy is still quite vulnerable to the Ricardian Growth Trap. To guarantee the lives of the poverty class that has the least means of coping with rising food prices, the supply and demand imbalance of foodgrains had to be adjusted in terms of quantity by import instead of price. Moreover, in India, where diverse social classes and provinces exist with conflicting stakes and where the election system is firmly established, the Government policies inclined to the Populism. Under such circumstances, increases in foodgrain price have to be avoided. It has been pointed out on the basis of experience that an inflation rate of more than 10% can lead India to political crisis. These situations mentioned so far have driven India into the external trap instead of the internal trap.

1-3 Industrial Stagnation: The Lost 10 Years

The mid 1960s agricultural crisis revealed the contradictory nature of the attempt to advance import-substitution industrialization on a fragile development fund procurement basis. This contradiction was not limited only to the short-term crisis cause by the droughts, but eventually ushered a long-term economic crisis that can be described as "the lost ten years". Table 1-2 shows the transitions of real growth rates of the nine major industrial sectors with high value-added production before, during, and after the lost ten years.

The declines of the growth rates are especially evident in the heavy industry sector (raw-material metals, metal products, and non-electric machinery) to which the Indian government allocated escalated development funds, while the slowdown of the growth rate in foods and cotton industries is relatively blunt. This fact implies that the downturn of growth rates was not owed to the internal trap of wage constraint. If wages had restricted the growth of the industrial sector, the growth rates would have markedly declined especially in the labor-intensive industries including food and cotton-product industries. This reasoning should refute the argument that the stagnating agriculture restricted the demand for final consumer goods and that the limited supply of agricultural products as raw materials constrained the industrial sector's output.

The major causes of the economic stagnation during this period can be related to the limited development funds due to the constraints on foreign reserves. The results of this bottleneck had two aspects. First, it was observed as a decrease in imports of capital goods as well as in the number of technological collaboration from the mid 1960s (Figure 1-5). The other consequence is that the agricultural crisis required a political change from industrially oriented to agriculture-oriented strategles, as will be mentioned later. The industrial sector's real capital formation increased rapidly as soon as the second 5-year Plan was introduced (Figure 1-6), but it floundered at a low level during "the lost ten years" from the mid 1960s to the mid 1970s, whereas that of the agricultural sector was increasing. In other words, while the size of development funds itself was restricted, more and more funds were allocated to agriculture and the industrial sector's narrowing path to fund source became obvious.

Why, then, did the economic stagnation last as long as ten years? The reason can be sought again in agriculture. India needed ten years after the agricultural crisis to get out of the external trap by means of "Green Revolution" that aimed at increasing foodgrain production. This was not only because ruin was needed for the diffusion of the Revolution. The country needed to import chemical fertilizers since a great amount of input of them was a necessary condition of the Green Revolution. The proportion of imports of chemical fertilizers plus foodgrains ("agricultural-related imports" hereafter) to the total imports was less than 20% before the agricultural crisis, and increased to 23.3% in fiscal 1964, then to 25.4%, 36.5%, and 33.2% in the following three years. The average rate for the period from the agricultural crisis to fiscal 1975 was 24%, which made the foreign-reserves constraint severer for import-substitution industrialization.

It went down below 10% only in fiscal 1977, and since then, the machinery import index and technological/collaboration have been reviving. Before this point is the lost ten years of the external relationships viewpoint.

From what has been discussed here, we can conclude that the statuses in balancing between population and food supply have substantially affected the industrialization strategies in India.

2. Turning to Agriculture-Oriented Policies: Green Revolution and Agricultural Problems

The agricultural sector, which was becoming a burden on economic growth, forced the Indian government to change their industry-preferred policy to an agriculture-oriented one. When the agricultural crisis occurred, the exploitation of arable land was approaching limit, and any increase in crops had to rely on improvement in land productivity. During the same period, many other developing countries were relying on imports of foodgrains also to cope with the population growth. To deal with such situations, a new agricultural method based on the high yielding varieties of wheat and rice, called the Green Revolution was developed. India is probably one of the countries that received the most benefit from this method.

With the increase in foodgrain output due to the Green Revolution, India began to depart from reliance on foodgrain imports. However, the increased production only substituted for import and no fundamental changes were observed in the supply demand situation of domestic foodgrains, given that there were no changes in the per-capita daily foodgrain consumption between pre- and post-revolution periods. Moreover, while taking it out of the Ricardian Growth Trap, the Revolution created new problems in the Indian economy. Let us review the process from the viewpoints of increased gaps between provinces (Section 2-1) and farmers' involvement in the market economy (the market nexus) (Section 2-3). These elements will lead to arguments regarding two de-stabilizing agricultural factors in the Indian economy; farmers' movement as pressure groups and potential food shortage of the future, which will be discussed in Chapter 3.

2-1 Regional Gaps

The Green Revolution is represented by the farming system based on the combination of high-yielding varieties, irrigation and chemical fertilizers.

The introduction of the high-yield varieties, that require the establishment of agricultural infrastructure based on irrigation, brought about the agricultural policy of pursuing efficiency rather than equality. In other words, it was a conversion from the development of farming areas by a Populism-type principle of equality to an intensive agricultural-area programme (1964/65) that invests mainly in the areas with relatively well-established infrastructure. The land productivity by province implies that the Revolution spread especially to the areas with irrigation systems (Figure 1-7). As a result, granaries were formed in the northwest areas consisting of Punjab, Haryana and the western part of Uttar Pradesh, where irrigation canal networks have been maintained since the colonial. When the Revolution had more or less spread in the late 1970s (1978/79), Punjab and Haryana, together occupying only 5.5% of the country's total farmland, produced 25% of the national output of wheat and nearly 10% of that of rice. These two provinces supplied about 70% of foodgrains procured by the Government for its buffer inventory and low-price sale to the poverty class. Indeed, these provinces feed India, and are the base of its food security.

The regionally biased diffusion of the Green Revolution meant widened regional gaps. Let us see changes in per-capita foodgrain output by province (major 15 provinces) during the four periods including the pre-revolutionary period (Table 1-3). Rapid increases in excess amount of foodgrains are found in Punjab and Haryana (The old Punjab was separated into these two provinces in 1966.). For this reason, these two provinces enjoy the highest per-capita income level, without having any major industrial areas. The coefficient of variation of their per-capita foodgrain output among states of India has also increased to 80 now, up from 36 before the Revolution, causing greater differences in excess marketable surplus between states. Comparison of transfers of foodgrains (6^{th} and 7^{th} row) between states before and after the Revolution reveals substantial increases of outgoing foodgrains in Punjab, Haryana and Uttar Pradesh, where the Green Revolution penetrated, and overall increase of incoming foodgrains in other states. Needless to say, the differences of irrigation rates are the major factor of such changes.

Figure 1-8 compares the distribution of per-capita expenditures of land owners and agricultural laborers in the two advanced provinces in the northwest area, and Bihar, known as the poorest state, during the period when the Revolution made a degree of progress.

In any of these states, cultivators' incomes are higher than the agricultural laborers', displaying the gaps between the classes within each state, as is often pointed out. However, more attention should be given to the fact that even the expenditure distribution of the agricultural laborers (the poorest rural class composing 30% of the total agricultural population of India) in the northwest area almost overlaps that of Bihar's cultivators. This tells us the scale of the Revolution's impact on rural communities, which can be also observed in the rates of populations below the poverty line (Table 1-4). The rate of the poverty class is already under 10% in Punjab, while that in Bihar is quite high - only second to that in Orissa. Further, the rate of the below-poverty line population among agricultural laborers in the northwest provinces is less than the rate of cultivators in Bihar (Table 1-5).

We now see the outcome of the self-sufficiency in foodgrain-supply attained by India. The self-sufficiency in foodgrain-supply achieved through the Green Revolution means only no import of foodgrains, and the abandonment of the vast poverty class suffering from food shortages. The process, in which considerable inequality was maintained in distribution of land-based assets without taking any effective measures, was to become a factor disturbing the Indian economy. This point will be discussed further in the following sections.

2-2 Irrigation in India

The greatest cause of regional gaps is the difference in progress of the Green Revolution, behind which differences in irrigation rate exist. However, irrigation rates alone cannot explain the progress of the Revolution. As shown in Tables 1-6 and 1-7, during the 20 years from fiscal 1970 to fiscal 1990, the irrigation rate for wheat production improved by 25 percentile points, whereas that for rice production rose only 7 points. The rates of increase in planted areas for and output of wheat are also relatively high. Indeed, the Green Revolution was a revolution of wheat.

What then made the difference between rice and wheat? The greatest reason is that the high-yielding varieties of rice require more intensive water management than those of wheat. Therefore, the Green Revolution was successful for rice only in the fields where water management was good. As observed from Figure 1-7, the land productivity for wheat reaches 3 ton per hectare when the land is fully irrigated, and can be 1.5 to 2 ton even at 20 to 40%. On the other hand, while the productivity for rice is 3.5 ton per hectare or above in Pubjab or Haryana where the irrigation rate is nearly 100%, it is as low as 1 to 1.5 ton where the irrigation rate is 50%. In other words, the irrigation effect on rice is relatively greater, meaning that rice is a crop requiring intensive irrigation. Therefore, the Green Revolution started with introducing high-yielding wheat, and it was applied later to rice that require more water management.

To enable good water management on a certain scale of farmland, canal irrigation and tube wells are effective methods. For canal irrigation to function properly, a water users association necessary is, managing allocation of water and collecting water charges. However, maintenance and management of canal irrigation involves a number of outstanding problems and not in India alone. In reality, water charges collected cannot even reach 50% of the requirement. Furthermore, construction of canals requires a great deal of public investment, and this issue is at deadlock in an India that suffers from a budget deficit, as will be mentioned later. For these reasons, tube wells, that enable efficient water management, are essential for the introduction of high-yielding varieties especially of rice. In recent years, increases in land productivity have been observed in poor provinces such as West Bengal around the lower-reaches of the Ganges, and Bihar. This is because tube wells have been constructed.

Also essential for efficient irrigation are land consolidation of farmlands. One of the bottlenecks of Indian farming is the fragmentation of land holdings. This is the obstacle against construction of tube wells with some economy of scale, and impedes efficient use of water resources by making operation and management of canals difficult. The necessity of land consolidation has been pointed out since before independence, and some efforts began to be made in the old Punjab including Haryana in the British colonial era. This movement expanded to a full-scale project, which had been completed by the 1960s in Punjab and Haryana, so that these states were ready to meet the system requirements of the Green Revolution.[1] In Bihar and West Bengal, however, land consolidation has hardly made any progress.

Moreover, while the northwest provinces standardized the unit - lot as one square acre square through land readjustment for exchanges and consolidations, the best attempted by the downstream Ganges area was only exchanges of lands and no standardization was made in terms of the forms of farmland.

Naturally, the rectangulation of fields allows effective design of canals, which then makes water distribution more efficient, and enables mechanization effective. But with the status quo, where land ownership is multi-layered as the result of an attempt to evade tenant farming problems and land reform laws, the economically efficient projects of land consolidation have hardly made any progress[2]. Thus, in the downstream Ganges areas, food production has been increased mainly by farmers who have relatively sufficient funds and large farmland such as to enable the installation of tube wells. This situation implies limitations on increase in production and involves the risk of drawing the income distribution in the rural communities towards further inequality.

2-3 Farmers and Market Nexus

The Green Revolution drew the farmers through various paths into the new world – a market economy. Let us discuss the farmers' market nexus (the degree of involvement in a market) in terms of products and input resources.

Figure 1-9 shows the rate by scale of wheat (winter crops) marketed by farmers in Pubjab, at the time the diffusion of the Green Revolution was almost completed. The rate becomes positive at about 0.4ha of landholding, reaches 50% at the scale of about 0.6ha, and then 90% at about 3ha. Since the average size of landholding in Pubjab is 3.77ha, almost all farmers are considered to market their wheat. Because this region is not a rice-eating one, most of their rice (summer crops) is transported to other states. These tendencies are more or less the same as in Haryana and western Uttar Pradesh. In these regions, newly emerging well-off farmers having market surplus have formed a new social class. Such data are not obtainable from most other states, so let us review the research data of Bihar (Table 1-8, Research conducted in 1979-81), for example. In 1 to 2 ha of farm size, surplus crops for marketing are not generated. Even for the farmers having 10 ha of farmland, the rate of marketable crops is only 67%. In view of the fact that the average farming area in this province is only 0.86 ha, only less than a quarter of that in Punjab, and its productivity is only a third that in Punjab, it is clear that even an average farmer has difficulties in self-sufficiency. The trend of the market price of crops must be a major concern for the farmers with surplus crops, but the market nexus in the form of sale of surplus crops is greatly affected by the farmland areas managed by farmers as well as the region they belong to.

Accordingly, the farmers' reactions against the market prices of crops vary depending on the degree of the market nexus.

Let us now review agricultural inputs. Table 1-9 compares the production-cost structures for rice in the developed northwest states and Bihar. The proportions, against the total production costs, of modern input resources, that require cash expenditure for farm equipment, seeds, chemical fertilizers, insecticides, and irrigation, is 59.47% in Punjab and 43.87% in Haryana, while that in Bihar is only 19.53%. The degree of the market nexus with regard to inputs modern is also higher in the north western area of India, and lower in poor states including Bihar. Consequently, the farmers promoting the Green Revolution feel greater concern over the trend of prices of the modern inputs, which are affected by, agricultural policies.

Attention should be paid to not only increased food production as an effect of the Revolution, but also the strengthened market nexus of farmers in terms of both marketable surplus and modern inputs such as chemical fertilizer. The market nexus, in conjunction with regional differences in diffusion of the Revolution and the size of landholding, diversified stakes of farmers involved in the agricultural policies. A policy of raising market prices of crops, for example, could please the farmers in the northwestern

India, but would not induce any increase in production by the Bihar farmers with no marketable surplus crops. Moreover, such a policy would impose higher living costs on non-self-supply farmers who had to buy foodgrains. While pursuing economic growth without any political reform related to agricultural production, such as land reform, India was confronted with not only the limited procurement of development funds, but also difficulties in trying to adjust different interests caused by the gaps between or within regions arising from the Green Revolution. These problems, combined with other political issues, became de-stabilizing factors in the Indian economy.

The increase in foodgrain production, that began in the mid 1960s due to the Green Revolution, eventually pulled the Indian economy out of the structure of dependence on foodgrain imports. Nonetheless, given that we can see no changes in the per-capita daily foodgrain consumption, the increased output of foodgrains only replaced imports, without bringing any fundamental change in the domestic supply and demand for foodgrains. Since the new agricultural method relied on chemical fertilizers, the proportion of agricultural-related imports including chemical fertilizers against the total imports had been relatively high until the fiscal 1977, and this crowded out imports of capital goods and technologies necessary to promote industrialization.

This can be confirmed, for example, by the fact that the US dollar based index of machinery imports dropped after the Revolution, and was unable to revive for some time (Figure 1-5). Thus, from the agricultural crisis till the late 1970s, the Indian economy experienced the so-called "Lost ten years" of stagnation, caught in the "external trap"[3]. The ratio of imports of agricultural resources to total imports started to decline, thanks to the Green Revolution, in the latter half 1970s. At the same time, the Indian economy finally got out of the external trap, and started to prepare conditions for the free economy to commence in the 1980s[4].

3. Second Agricultural Reform and Farmers' Movement

3-1 Change in Agricultural Policy

As shown in Figure 1-4 earlier, despite the strained supply demand situation in foodgrains during and before the 1960s, the terms of trade between agriculture and industry moved disadvantageous to agriculture under the industry-oriented economic policies in which foodgrain prices, as wage goods, were kept low by means of imported foodgrains. But the terms of trade became increasingly advantageous to farming after the agricultural crisis as government measures promoted the Green Revolution in which agricultural subsidiaries increased and the buying prices of foodgrains were raised.

The conversion to agricultural-oriented government policies changed the areas, such as the northwest India, with established infrastructures, into the granaries of the country. Part of the result can be observed in relation to institutional credit to Agriculture (Table 1-10). The rates of borrowings from public financial institutions in Punjab and Haryana are relatively high, as well as the share of agricultural capital investment in the total loans. As a result the expenditures for fixed capital formation are the greatest. The fixed capital formation per farming household were Rs915 in Punjab and Rs652 in Haryana, whereas those in Bihar and West Bengal were Rs43 and Rs54 respectively. This is how the close relationship started between the newly emerging well-off farming class and a Government taking the agriculture-oriented policies - through the support price system and various subsidiaries.

The Green Revolution resulted in drastic decreases of foodgrain imports, and saved India from the Ricardian external trap. Such subsidiary policies, however, would provoke a financial crisis.

Taking this situation into account, The Committee on Taxation of Agricultural Wealth and Income revealed that Punjab's agricultural taxation was only 0.42% of its agricultural income, and proposed an income transfer from wealthy farmers by taxation. The proposal was not accepted by a provincial government, that possessed the authority to impose taxes but feared wealthy farmers' resistance. Under the circumstances, the central government was forced to reduce agricultural subsidies and review the crop price system. As a result, the prices of modern inputs rose, and real farmgate prices of foodgrains at fell. Accordingly, the terms of trade became increasingly unfavorable to agriculture in the latter half 1970s, when there was almost no need of imported foodgrains. This means that a favorable environment was prepared for industrialization, which led to resuming liberalization of economy. This trend naturally provoked wealthy farmers' resistance as reducing their revenues, and immediately put an end to the good relationship between the new wealthy farming class and the Congress. The Punjab riots and assassination of Prime Minister Indira Gandhi in the 1980s are the extension of this current.

3-2 Farmers Turning To Pressure Groups[5]

As the terms of trade between the agricultural and industrial sectors were becoming disadvantageous to agriculture, the New Farmers' Movements grew active. The core of these movements were not the peasants (traditional farmers) but the modern farmers (commercial farmers) who had marketable surplus and were involved in the market economy as purchasers of modern agricultural inputs. The common features of the new farmers' movements were "anti-state" and "anti-urban", as symbolized in "India (Urban India) vs. Bharat (Rural India)" – the slogan of Sharad Joshi, who was the ideological mainstay of the new movements. The slogan of the former farmers' movements before the Green Revolution was "Land to the Tiller", and their political issues concerned land reform or the tenancy problems. But the 1970s new farmers' movement involved issues related to the market nexus such as price of crops and modern inputs, or subsidies, and encouraged lobbying activities.

With the 1977 general election, the Janata (People's) Party came into power, defeating the Congress.

Not surprisingly, Janata involved the wealthy farming class representing the new farmers' movements. This period was the turning point for India's agricultural policies. Unlike the former ruling party, the Janata Party pursed policy operations strongly characterized by the Populist type strategies due to its weak political base. In those days, policies in favor of agriculture, especially commercial farmers' interests, had been employed. The new farmers' movements were even more conspicuous in provincial governments. The activists, however, maintained their position of belonging to no party or faction, and extended typical rent-seeking lobbying activities in which they changed the parties they supported according to their requirements. As the farmers' movements came to directly affect outcomes of elections, the government became reluctant to take policies that might conflict with farmers' interests. As a result, it procrastinated, cutting agricultural subsidiaries despite the fact that the foodgrain buffer inventory had already exceeded the appropriate level and the budget deficit was deteriorating[6].

However, as discussed earlier, the degree of the market nexus various considerably depending on classes of the rural communities or on regions. So, the farmers' movements have been diversified without being confined to the simple "urban vs. rural" framework. In recent years, local political parties have made remarkable progress on India's general elections, and this trend is considered as representing diversified farmer interests. Since the demise of the Congress Party's monopolistic advantage, India went into an era of coalitions falling into political chaos. If the reasons for the situation include conflicting interests deriving from the measures against agricultural problems, the disorder of Indian politics will not be easily resolved.

Rising market prices of foodgrains would not only reveal the problems of Ricardian Growth Trap, but also provoke consumer resentment, which would lead to parliamentary reshuffles. On the other hand, falling crop price at farmgate would repel commercial farmers, and lead to political instability. Standing between producers and consumers - the two classes with conflicting interests, - the Government has been compelled into populist political operations, and had been forced to purchase vast amounts of foodgrain, in order to maintain the level of the farmgate crop prices, despite the record-high level of the buffer inventory and growing concerns over the excess stocks. The Government's buffer stocks levels from 1980 to 1997 (records as of January 1st each year) averaged 17.21 million tons (SD 6.26 million ton), and the peak was as high as 36.54 million tons (June 1995). The scale of the buffer stocks should be evident in view of the fact that the foodgrain output for the period was 153.1 million tons (SD 17.38 million tons) and the rate of marketable crops was about 40%.

This cannot be explained by any economic logic, but is probably the result of pressure from the new farmers' movements and their lobbying activities. The foodgrains bought by the Government have been sold to the poverty class at prices lower than the Government's buying prices at more than 400,000 "fair-price" shops under the Public Distribution System (PDS), and the negative spread is subsidized by increasing the budget deficit. Although the buffer stocks are above the appropriate level, the rationing prices are still kept low even in the 1990s while the government buying prices continue to rise. India started to import foodgrains in the latter half 1980s, but in view of the vast population below the poverty line, this could be called "hunger export". Nonetheless, reduction in the foodgrain price by releasing the excess stocks to the market, which would please the poor, would provoke the anger of farmers with marketable surpluses, widen the negative spread, and increase the budget deficit. India is in a dilemma such that it has to maintain economically inappropriate agricultural policies while the inventory tends inevitably to accumulate further. Moreover, the considerable amount of expenditure on agricultural subsidiaries, generated for political reasons, has brought about budget deficit as well as a distortion of the markets related to agricultural production, and may hamper establishment of the country's competitiveness in the international agricultural market. In addition, it has created a new problem in as much as public capital formation on the agricultural sector is decreasing.

4 Problems in Agricultural Fixed Capital Formation

4-1 Deteriorating Budget Deficit

As economic liberalization was proceeding in the latter half of the 1970s, the trade deficit due to increased imports was beginning to expand. Early in this period, India still held relatively abundant foreign exchange reserves, since its agricultural imports had already fallen, and money was being remitted from Indian laborers working abroad. For example, its remittance receipts in fiscal 1980/81 amounted to US$2.7 billion, which played an important role as buffer against the trade deficit (US$7.38 billion for the fiscal 1980/81). Therefore, the trend of relaxing import regulations was maintained, increasing the imbalance of international payments that had been more or less balanced till then (Figure 1-10). In this process, India was hit by the lean harvests of 1979 and 1980 (a 17.6% negative growth of foodgrain production from a year earlier) and the economic crisis provoked by the second oil crisis.

The ruling Janata Party, unable to control the economic disorders collapsed after internal disagreements, and in 1980 Indira Gandhi returned to power. Her administration was, however, also built on a vulnerable base, having to follow policies inclined to the populism based on the subsidies of the Janata era. As a result, central government budget deficit against GDP only continued to increase, and its proportion reached about 8% in the latter half of the 1980s. In the meantime, the Government's outstanding domestic debts exceeded 50% the GDP in the latter half 1980s, up from 35.6% in fiscal 1980/81, significantly derailing the country from balanced finance.

Likewise, the trade deficit swelled considerably great, with a record worst ratio to the GNP, with Indira Gandhi was back in office (See Figure 1-1). She attempted to overcome the economic crisis with US$5 billion loans, by means of the SDR (Special Drawing Rights), from the IMF Extended Facility Fund – the greatest amount the IMF had ever lent to member countries. The Extended Facility Fund offers conditionalities, thereby various liberalization measures were introduced in industrial and trade policies. Unfortunately, such liberalization conflicted with the self-reliance spirit, which is part of Indian economic philosophy. Those measures, together with the bitter experiences in the latter half of the 1960s, provoked strong resistance in the country. Against this background, the basic framework of the controlled economy system remained. Thus, this period can be characterized by liberalization of the economy while a system of controlled economy was maintained.

Whilst the manufacturing sector achieved a relative growth rate of about 7% throughout the 1980s in the process of economic liberalization, the trade balance was destined to stay in the red, in exchange for the import-substitution industrialization. The trade-deficit rate of GNP during this period was as high as mid 1960s levels (See Figure 1-1). The current-account deficits in the first half of the 1980s were financed mainly by aids from abroad, whereas in the second half of the year, the proportion of borrowing from overseas Indians' deposits and foreign commercial banks gradually increased. The aid from foreign countries and borrowings for external trade made the debt service ratio surge, and, in the mid 1980s, exceed 25%, which is the critical level. Moreover, overseas Indians' (NRI) deposits largely tend to be hot money, so the funds were recalled on a large scale at the time of the 1991 economic crisis, making the situation even worse. With the growing current-account deficit, A macroeconomic environment was gradually formed, just like that of Thailand immediately before the 1997 monetary crisis.

With the defeat of the Congress in the 1987 general election, politics also has gone from one unstable coalition government to another.

Let us briefly review the background of the macroeconomic imbalances (trade deficit and budget deficit) that were tolerated. Traditionally, India took so-called stop-go policies to maintain macroeconomic balances, but this equilibrium principle began to collapse in the latter half of the 1970s. The logic behind it can be explained as follows. The Green Revolution brought farmers into the market economy with the aim of self-sufficiency in food-supply, and formed a multi-layered wealthy farming class (positioned as the middle class in the overall social structure) sensitive to prices. The poverty class also became sensitive to the price of food in the public distribution system by which foodgrains were supplied at lower price than the market price. Consequently, as the subsidies increased, farmers and the poverty-class people turned into "rent seekers" through democratic elections. This process was the phenomenon that is said to have brought about political awakening as well as political decay, and such rent-seeking communities, as called by Kruger, spread in the agricultural sector and among the low-income groups. As the ruling parties in recent years have no possessed firm monopolistic advantage since the latter half 1970s, the political operations have been more and more inclined towards populism with society increasingly in pursuit of rent. Government expenditure has not been appropriately controlled and the macroeconomic imbalances have been revealed. While many argue about development and democracy (or development dictatorship), in the democracy in India, negative aspects affecting its development have come to the fore.

4-2 Trends of Agricultural Fixed Capital Formation

The trend of agricultural fixed capital formation is one of the central disputes over today's Indian agriculture (Figure 1-11). On this issue, it is argued (1) that the growth of real capital formation in the agricultural sector stumbled in the 1980s, and (2) that the private sector's capital formation began to increase, whereas that of the public sector started to decline in the mid 1980s, so that thereby the growth rate of the agricultural sector's capital formation is more or less edging up.

As public and private investments had paralleled until the mid 1980s, public investment was said to induce private investment, and therefore, the ceiling, that capital formation by public investment might hit was feared to exert negative effect on the private investment[7].

However, new theories have been required to explain the divergent trends of capital formation by public and private investments since the latter half 1980s. Special attention should be paid here to the fact that even though no significant changes were found in the terms of trade between agriculture and industry that were disadvantageous to the former in the latter half of the 1970s, agricultural fixed capital formation by the private sector has been increasing since the latter half of the 1980s.

The private sector's capital formation tentatively surged upward in the late 1970s. But if we regard that period as an anomaly, the increase has kept relatively constant. In 1977, the Janata Party came into power, and the Congress went out. The Janata Party was compelled to take strongly populism-oriented government policies due to its weak political base. Furthermore, in the core of the party was Charan Singh, the representative of the wealthy farming class of the western Uttar Pradesh granary belt[8]. He even served as the Vice Premier and Finance Minister, albeit for a short term. In those days, the government policies turned in favor of agriculture, especially the interests of commercial farmers. One typical example was the increase of subsidiaries for agriculture including credit[9]. Since such subsidies become vested interests for the beneficiaries once introduced, the ratchet effect impeded efforts to reduce them. After all, the New Congress Party, back in office, was not able to engineer any reduction, no more than their predecessor. How much impact the political measures had on private capital formation in the agricultural sector has not been identified. However, in view of the proportion of the agricultural-institutional loans to the total of private fixed-capital formation for the agricultural sector, which surged to 60% in the 1980s, up from 29% in the 1970s, it is obvious that the

Government's financial support to private sector capital formation has increased (Figure 1-12)[10]. Nonetheless, the budget deficit, becoming full scale, forced the Government to cut development expenditures, and private and public capital formations started to diverge in the agricultural sector from the latter half 1980s onwards[11]. The central government sees problems in the reduction of public investment for agricultural fixed capital formation, but it regards them as "under the control of the states"[12]. State governments' financial statuses are, however, even worse than that of central government, and many projects for canal construction are stumbling at the planning stage.

The private sector's fixed capital formation is concentrated on such capital goods as tube-wells and tractors, typically with little external economy. On the other hand, public capital formation is decreasing, which is supposed to be effective for the establishment of agricultural infrastructure able to exert external impact, such as canal irrigation etc. This tendency may endanger India's long-term food security, even if we ignore its low farmland irrigation rate, which is only slightly above 30%.

5. Food Problem – No Longer a Political Issue?

The Indian government is, in general, quite optimistic about the country's self-sufficiency in food-supply. This optimism is backed by the buffer inventory level, which was marked a record high thanks to recent good monsoons. Of course, the possibility of resuming import of foodgrains cannot be excluded because of the irregular advents of monsoons that are experienced at times. But India's self-sufficiency in food-supply can be presumed to be sufficient on the short- and mid-term basis. The issue is the long-term supply.

Among the forecasts of India's future demand for food, those for foodgrains for 2010 vary in the range between the 1.91 to 2.05 million tons, the forecast by the World Bank to the 2.43 to 2.59 million tons, forecast by

G.S. Bhalla[13]. The low values represented by the World Bank's forecast are based on the assumption that demand for foodgrains will diminish along with economic growth. On the other hand, Bhalla's high forecast values presuppose increases in demand for feed crops deriving from demand for milk, dairy products, meat and eggs, all with an income elasticity greater than 1, expected to rise in line with economic growth. Verification of those estimates is beyond the scope of this report, but the following facts must be considered.

Figure 1-13 shows per-capita foodgrain consumption (rice and wheat separated) of each expenditure group in the major states, whereas Table 1-11 displays the expenditure elasticity of major foodgrain (rice and wheat) consumption[14]. These data demonstrate the following three points. Firstly, elasticity in the rural area is 0.42, which is significantly high. It must be noted that foodgrains are not inferior goods even for the high-expenditure (i.e., high-income) groups, therefore, the high rate of increase in demand for foodgrains regarded as likely to continue for a time in the process of the economic growth. In the low-income states, the consumption of minor cereals including millet and maize is second greatest. Increases in income may shift the demand from such cereals to the major foodgrains. For example, the expenditure elasticity is unusually high in Karnataka and Gujarat. This is because the consumption of minor cereals mentioned above is greater than that of rice or wheat, and such minor cereals became inferior goods for the high-income groups, shifting their consumption to rice and wheat.

Taking this sort of shift into account, it is very likely that the World Bank has underestimated the demand trend. Secondly, the presence of substantial differences in foodgrain consumption between groups (classes) will radically change widely the structure of demand for foodgrains, as income distribution varies in the process of economic growth. Thirdly, expenditure elasticity in foodgrain consumption is relatively high in the areas where rice is the staple food. So, if other conditions remain constant, the demand for rice, not for wheat, is expected to increase.

If we assume that the national-average expenditure elasticity in foodgrains is 0.4, and that the annual growth rate of per-capita real income remains at 5%, then demand for foodgrains would increase at a rate of 2% per annum. Considering the 1.9% of the population growth rate, the total rate of increase in demand for foodgrains is expected to be about 4%. This rate will double the demand over some 18 years. If incomes rise, the elasticity will naturally fall. On the other hand, if demand for feed crops increases, deriving from rise in demand for meat, much reduction in the elasticity cannot be expected. In talking about the food problem in India, its population has generally been focused on. If the country's economy continues to grow, however, income effect will be a matter of concern greater than the increase in demand for foodgrains.

Would it then be possible to increase foodgrain production to meet demand in the process of economic growth? The diffusion of high-yield varieties has been almost completed in the advanced farming states, and much extension of cultivated area cannot be expected in India – and not merely in the northwest regions. Accordingly, farming productivity (land productivity) needs to be raised in the agriculturally backward states, in order to cater for India's demand for food. Without greater productivity, the demand-supply imbalance between states would increase, and regions' conflicting interests would be more serious, narrowing the choice of policies.

The increase in production of rice in recent years in the states along the lower reaches of the Ganges (West Bengal, Bihar, and Orissa) is a desirable tendency. The increased production has been achieved by construction of tube wells. There is doubt, however, as to whether this trend will create a granary belt in these areas as is seen in the northwest of India.

Considering this situation, if a food crisis is impending, India will be compelled to increase food production in the areas backing sufficient agricultural infrastructure, including irrigation and land consolidation.

If this happens, the country will have to confront the difficulties of increasing yield in an environment which is different in quality from that of the mid 1960s, when it could resort to the infrastructures inherited from British India. In this context, the status quo contains incorporates serious problems for long-term food security, with agricultural infrastructure mainly built through private investment without much external economy, and with the public investment which could exert external economy through, for example, construction of canals decreasing.

6. Economic Liberalization and Agricultural Problems

The disequilibrium of the Indian macro-economy led to the economic crisis of April, 1991 in which the foreign exchange reserve dropped as low as a two-week share of the annual imports. India attempted to overcome this grave situation by Structural Adjustment Loan (SAL) from IMF and the World Bank. The loan with conditionalities eventually forced the economy into liberalization. At this point in time, India's budget deficit was at the critical level.

The first chapter of the Economic Review 1991, Fiscal Policy" began as follows.

The fiscal situation, which was under strain throughout the 1980s, reached a critical situation in 1990-91 with a sharp deterioration in the revenue deficit. Fiscal deficits generates pressure on inflation as well as on the balance of payments. The gross fiscal deficit of the Central Government, which measures the total resource gap, has been more than 9 per cent of GDP since 1985-86, as compared with 6 per cent at the beginning of 1980s and 4 per cent in the mid-1970s. Such fiscal deficit are unsustainable and would lead the country into a debt-trap. The unabated growth of non-plan expenditure and poor returns from investments made in the public sector have been the main contributory factors in the fiscal crisis.

Since the major cause of the fiscal deficit has been the subsidies to the agricultural sector (chemical fertilizers and foods), any cut in such expenditures would provoke vested-interest groups' resistance. This problem would not be easily solved without a ruling party with a monolithic majority. From another point of view, subsidies for food to maintain the public rationing system can be considered as providing the vast poverty class with a safety net. Even though provision of the safety net may conflict with the market mechanism, it is based on political ideology in the context of Indian society.

Removing government intervention may magnify economic efficiency. But if the intervention, on the other hand, is enhancing social welfare, its removal, i.e., economic liberalization, must be balanced with some measures to complement the loss of welfare.

Despite the record-high level of its buffer stocks, the Government has been unable to reduce the purchasing price of foodgrains, for fear of farmers' resistance. In spite of the existence of the vast population under the poverty line, neither has it cut the rationing price, as any such reduction could augment the budget deficit. Solving this greatest dilemma of agricultural policy should be the critical issue for Indian agriculture in the years to come.

Note:

1. As well as land consolidation of lands, leveling has been undertaken. This is an important infrastructure project for enhancing efficiency of irrigation.
2. For example, the rate of conversion to the high yield varieties (rice) was about 15% in the mid 1970s, and eventually reached 30% in the latter half of the 1980s. As for wheat, where water management is easily, its HYV rate rose to 70% in the mid 1970s, but has since stagnated. Meanwhile, the HYV rates of both wheat and rice in Punjab had already attained 90% in the mid 1970s.

3. Although this paper explains the stagnation of the industrial sector by examining of the agricultural sector, the latter is only part of the cause. For details of controvercies over the industrial stagnation, refer to: Ahluwalia I.J., Industrial Growth in India: Stagnation since the Mid-Sixties, Delhi, Oxford University Press, 1985.
4. Economic Review 1977 holds forth quite an optimistic prospect: "The shortages of food and foreign exchange holdings, that have impeded our economic growth, will no longer be any constraint." This is also the dominant forecast from authoritative current government spokespersons.
5. Journal of Peasant Studies, Vol.21, No.3/4, April/July, 1994 gives extra space to special articles on the peasants' movements. A large part of the descriptions in this present paper is owed to this issue.
6. For farmers' lobbying, see Karnik A. & Lalvani M., "Interest Groups, Subsides and Public Goods –Farm Lobby in Indian Agriculture", Economic and Political Weekly, March 30, 1996, pp.818-820.
7. For example, see Rao C. H., Agricultural Growth, Rural Poverty and Environmental Degradation in India, Oxford University Press, Delhi, 1994, and Shetty S. L., "Investment in Agriculture, Brief Review of Recent Trends", Economic and Political Weekly, Vol.25. No.7&8, Feb.,1990, pp.17-24.
8. Charan Singh, who criticized the Urban (India) biased political strategies, and fought for Rural communities' (Bharat) benefits, maintained an anti-Congress Party stance, and served as a governor of Uttar Pradesh. Later, he led the Bharatiya Lok Dal Party, called several other anti-Congress Party forces together, and formed the Janata Party, which then replaced the Congress Party to head the Federal Government from 1977 to 1980.
9. Not only in India, but also in many other developing countries, percentages of debt collection under rural policy finance is only just over 50%, as farmers tend to regard the loans as subsidies.
10. Mishra S. N. and Ramash Chand, "Public and Private Capital Formation in Indian Agriculture –Comments on Complementarity Hypothesis and

Others", Economic and Political Weekly, June 24, 1995.pp.A64-A79....

11. The budget deficit rate of the GDP was about 5% in the 1960s and 1970s, 8% in the first half of the 1980s, and reached 10% in the latter half of the 1980s. See Joshi V.&I.M.D. Little, India –Macroeconomics and Political Economy 1964-1991, World Bank, Washington, 1994.
12. Government of India, The Central Budget 1995/96, New Delhi, 1995.
13. For details, see G.S.Bhalla, "Globalisation and Agricultural Policy in India" Indian Journal of Agricultural Economics, Vol.50, No.1, Jan-March, 1995, pp7-26. Bhalla forecasts that the economic growth rate for the period will be 3 to 5.5%. His forecasts of the population growth are 1.94% for the period from 1991 through 2001, and 1.80% from 2001 through 2011.
14. Both data of rural areas. This is because urban areas consume a great deal of food, such as foodgrain-processed foods or meats, which generate derivative demand for feed crops, and no data is available to convert such consumption in to the unit of foodgrains.

Table 1-1 Borrowings and Deficit Finance for 5-Year Plan on its Early Stage

(Composition of funds: %)

	1st Phase 1951-56	2nd Phase 1956-61	3rd Phase 1961-66
Domestic Loans	35.0	30.8	24.6
Deficit Finance	17.0	20.4	13.2
Foreign Capital	9.6	22.5	28.2

Source: Reserve Bank of India, Report on Currency and Finance, annual issue.

Table 1-2 Annual Average Growth Rate of Real Value-Added in Major Manufacturing Sector

	Foods	Cotton Products	Rubber & Petrolem Products	Chemicals	Raw Material Metals	Metal Products	Non-electrical Machines	Electrical Machines	Transport-ation equipment
1951/52-63/64	4.41	4.14	12.69	10.13	12.00	12.69	21.08	16.84	0.11
1966/67-75/76	2.60	2.66	10.13	8.10	3.82	1.25	6.21	9.44	0.01
1976/77-89/90	10.35	5.64	12.73	9.64	4.82	5.63	7.09	10.83	0.08
Rate of Value Added (%)									
1951/52	18.50	35.44	2.49	7.12	8.89	2.36	1.52	1.22	8.01
1980/81	6.69	12.40	4.86	14.67	12.31	2.87	7.79	7.27	7.97

Note: Data for the mid 1960s, when the economy was chaotic, are not included.

Source: Calculation based on "National Accounts Statistics of India-4", Economic and Political Weekly, December, 1995.

Table 1-3 Per-capita Foodgrain Output by State (kg)

State	1960 -62	1972 -74	1984 -86	1990 -92	Shipments of Rice and Wheat to other states (1,000 tons)		Irrigation Rate of Planted Area (%)
					1964	1988	
Punjab (PJ) and Haryana (HA)	313.5	454.0	734.9	796.4	285	7429 ↑	84.9
Uttar Pradesh (UP)	184.5	176.9	242.8	257.4	-663	2482 ↑	56.0
Bihar (BI)	158.6	140.0	136.9	123.4	-401	-812 ↓	41.5
West Bengal (WB)	147.5	151.0	154.6	178.8	-197	-1017 ↓	25.1
Assam (AS)	145.4	137.9	121.1	152.7	-249	-612 ↓	32.6
Orissa (OR)	225.1	200.1	217.1	222.4	17	-269 ↓	24.7
Andra Pradesh (AP)	180.8	175.3	161.5	178.9	786	924→	52.0
Jammu and Kashmir (J&K) and Himachal Pradesh (HP)	113.9	222.1	212.4	214.9	-4	-113 ↓	27.6
Rajasthan (RJ)	242.1	199.8	180.4	230.2	-78	-192 ↓	18.1
Gujarat (GU)	103.5	95.2	95.5	110.1	215	-209 ↓	23.2
Madhya Pradesh (MP)	273.9	231.4	237.2	253.8	387	150 ↓	20.4
Mahara shtra (MA)	165.0	110.0	120.7	146.1	957	-596 ↓	10.8
Karnataka (KA)	161.6	185.0	154.3	169.2	-184	-44→	19.4
Kerala (KE)	61.9	58.9	43.6	37.9	-301	-1299 ↓	38.0
Tamil Nadu (TN)	160.9	146.6	134.1	143.4	334	-813 ↓	48.5
Average of Major States	175.8	178.9	196.5	214.4			34.6
Coefficient of Variation	36.0	48.4	78.0	77.2			

Note: The foodgrain outputs are averages for each three-year period. The figures for Punjab and Haryana, and for J&K (Jammu and Kashmir) and Himachal Pradesh are totals for the combined states.

Source: The data in the first to the third columns are based on Utsa Patnaik, "Political Economy of State Intervention in Food Economy", Economic and Political Weekly, May 17-24, 1997. The shipments of foodgrains follow Government of India, Statistical Abstract, 1967 and 1989. The other data are the same as those in Table 11-1.

Table 1-4 Proportion of Population Under Poverty Line

	1972/73	1977/78	1983	1987/88
States in the Ganges Basin				
Punjab	13.89	10.24	8.48	6.99
Haryana	13.89	19.20	11.74	11.43
Uttar Pradesh	36.83	36.07	32.60	29.43
Bihar	52.24	52.22	50.54	40.40
West Bengal	60.96	58.59	48.64	34.67
Himachal Pradesh	11.75	22.72	11.06	9.56
Jammu and Kashmir	17.78	24.38	10.50	13.28
Assam	34.73	38.81	21.63	23.79
Andhra Pradesh	40.77	29.15	18.74	13.38
Orissa	66.92	62.54	50.29	46.22
Rajasthan	34.56	25.99	24.67	21.38
Gujarat	40.12	31.52	14.92	15.28
Madhya Pradesh	53.25	53.08	37.15	28.81
Maharashtra	56.74	54.27	34.28	31.23
Karnataka	34.27	38.37	27.81	23.47
Kerala	51.73	41.47	27.05	19.29
Tamil Nadu	45.97	48.34	40.79	36.00
Average	42.93	40.12	31.40	24.68

Source: Department of Statistics, Ministry of Planning, Government of India, Sarvekshana, Vol.2, No. 3, 1986; Vol.15, No.1, 1991.

Table 1-5 Proportion of Population Under Poverty Line by Class in Rural Communities (1983, %)

	Cultivators	Agricultural laborers	Villiage workers
States in the Ganges Basin			
Punjab	3.27	18.73	17.37
Haryana	8.72	24.53	24.07
Uttar Pradesh	32.64	51.83	48.32
Bihar	42.43	73.85	72.84
West Bengal	35.82	74.50	71.15
Himachal Pradesh	13.99	14.44	17.37
Jammu and kashmir	11.72	22.44	22.06
Assam	24.49	38.62	40.84
Andhra Pradesh	16.69	28.74	27.33
Orissa	51.14	68.30	67.68
Rajasthan	30.04	36.47	32.03
Gujarat	21.63	27.16	28.36
Madhya Pradesh	27.34	54.85	53.79
Maharashtra	32.12	52.40	48.94
Karnataka	24.44	41.59	39.05
Kerala	23.99	41.40	38.70
Tamil Nadu	34.82	56.78	53.66
Average	30.43	49.36	46.44

Source: Department of Statistics, Ministry of Planning, Government of India, Sarvekshana, Vol.13, No.1, 1989.

Table 1-6 Transitions of Planted Areas for Rice and Wheat (unit: million ha) and Irrigation Rate

	1970/71	1980/81	1985/86	1990/91
Rice	14.4(38.4)	16.4(40.5)	17.7(43.0)	19.2(45.1)
Wheat	9.9(54.3)	15.6(69.7)	17.5(76.3)	19.3(79.8)
Total Foodgrains	28.1(27.6)	35.8(33.8)	38.5(37.2)	39.5(37.8)

Note: The irrigation rates are shown in brackets.
Source: Economic Survey, 1993/94

Table 1-7 Production of Rice and Wheat (unit: million ton)

	Rice	Wheat	Wheat/Rice (%)
1950/51	20.58	6.46	31.39
1960/61	34.58	11.00	31.81
1970/71	42.22	23.83	56.44
1980/81	53.63	36.31	67.70
1990/91	74.29	55.14	74.22
1995/95	81.10	65.50	80.76

Source: Economic Survey, 1995/96.

Table 1-8 Size of Landholding and Rates of Marketable Surplus in Bihar

Farming Area	1ha or below	1.01-2ha	2.01-4ha	4.01-6ha	6.01-10ha	10ha or above	Average
Marketable-Surplus/Output Rate(%)	-18.5	-3.3	42.4	42.2	45.1	67.2	48.8

Reference: Prasad, J. Marketable Surplus and Market Performance, Mittal Publications, Delhi, 1989.

Table 1-9 Comparison of Production Cost for Rice (Rs/Ha)

	Punjab (1989/90)	Haryana (1989/90)	Bihar (1987/88)
A Labor			
Wage Labor	990.15	1042.98	511.87
Family Labor	492.06	715.91	657.50
Total	1482.21	1758.89	1169.37
B Draft Animal Labor			
Rented	2.16	0.04	28.46
Owned	200.55	168.19	519.61
Total	202.71	168.23	548.07
C Agricultural Machinery			
Rented	355.36	177.21	10.14
Owned	416.76	261.52	3.27
Total	772.12	438.75	13.41
D Seeds	155.64	152.98	146.70
E Fertilizers			
Chemical	894.24	626.36	242.34
Manure	95.55	37.66	67.15
Total	989.79	664.52	309.49
F Insecticide	220.13	192.16	0.00
G Irrigation	755.44	1121.25	42.68
H Others	126.03	118.15	49.15
Grand Total	4704.07	4614.91	2278.87

Source: Ministry of Agriculture, Government of India, Reports of the Commission for Agricultural Costs and Prices on Price Policy for Crops Sown in 1991 - 92 season and 1992 - 93 season, New Delhi, 1993.

Table 1-10 Farmers' Borrowings and Investments in Farming

	Rate of Borrowings from Formal Institutions (%)	Rate of Investment in Agricultural Capital to Borrowings (%)	Amount of Capital Investment per Household (Rs)	Fixed Capital Formation per Household (Rs)
Andhra Pradesh	43.53	38.11	841	187
Assam	20.37	18.28	363	51
Bihar	48.87	35.67	414	43
Gujarat	71.61	47.70	743	322
Haryana	80.35	65.31	1772	652
Himachal Pradesh	73.42	36.52	829	103
Jammu and Kashmir	45.82	19.23	1357	113
Karnataka	78.74	64.62	1261	253
Kerala	78.74	168.60	1671	135
Madhya Pradesh	67.46	52.58	640	151
Maharashtra	87.78	47.70	975	304
Orissa	83.46	44.79	450	38
Punjab	76.77	69.57	2336	915
Rajasthan	42.46	36.24	985	234
Uttar Pradesh	59.24	48.34	863	178
West Bengal	65.35	34.59	496	54
India Total	63.15	45.15	823	176

Note: The above figures represent tenant-farmers only. System financial institutions include commercial banks. Financial institutions here include landowners, moneylenders, and relatives.

Source: Gov. of India. Sarvekshana, Vol.XI, No.1, 1987.

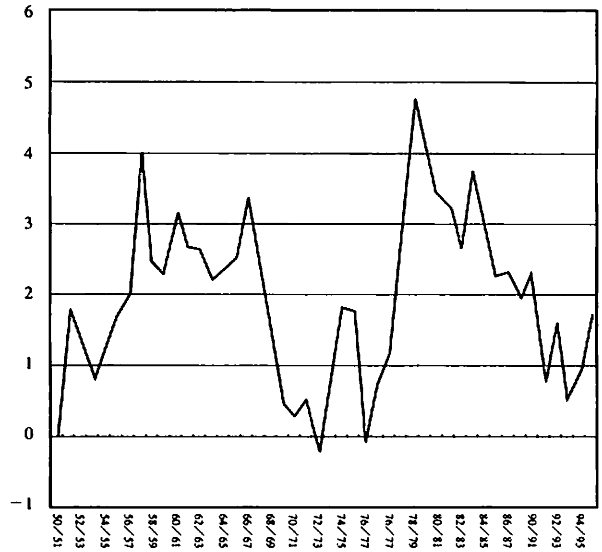
Table 1-11 Expenditure Elasticity in Rice and Wheat Consumption (1998)

		Elasticity	Coefficient of Determination	T-value
Andhra Pradesh	R	0.54	0.92	11.12
Assam	W	0.61	0.73	5.28
Bihar	R	0.48	0.89	9.22
Gujarat	W	0.78	0.95	13.98
Haryana	W	0.38	0.95	13.92
Himachal Pradesh	W	0.36	0.85	7.52
Jammu and Kashmir	W	0.59	0.86	7.91
Karnataka	R	0.88	0.88	8.43
Kerala	R	0.49	0.92	10.47
Madhya Pradesh	W	0.45	0.80	6.28
Maharashtra	W	0.64	0.89	9.11
Orissa	R	0.40	0.90	9.45
Punjab	W	0.44	0.86	7.69
Rajasthan	W	0.43	0.92	10.88
Tamil Nadu	R	0.56	0.92	11.02
Uttar Pradesh	R	0.37	0.94	12.50
West Bengal	R	0.47	0.88	9.53
Average for Indian Rural Areas		0.42	0.86	7.96
Average for Indian Urban Areas		0.25	0.89	9.22

Note: R and W denote rice and wheat. Elasticity is obtained by the following equation.
log(Per-capita consumption of rice and wheat) = a+b log(Per-capita expenditure).
Since data on incomes is not available, expenditures substitutes for the former.

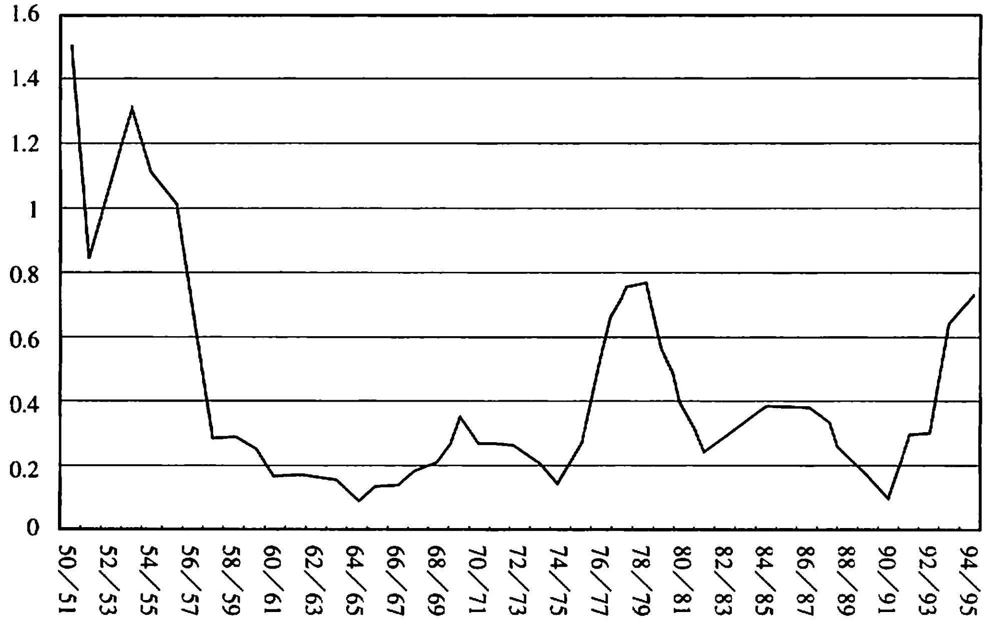
Source: The same as for Figure 2-13.

Figure 1-1 Trade Deficit Rate of GNP



Source: Based on Government of India, Economic Survey 1996/97.

Figure 1-2 Ratio of Imports to Foreign Exchange Reserves



Source: The same as Figure 2-1.

Figure 1-3 Ricardo's Growth Trap

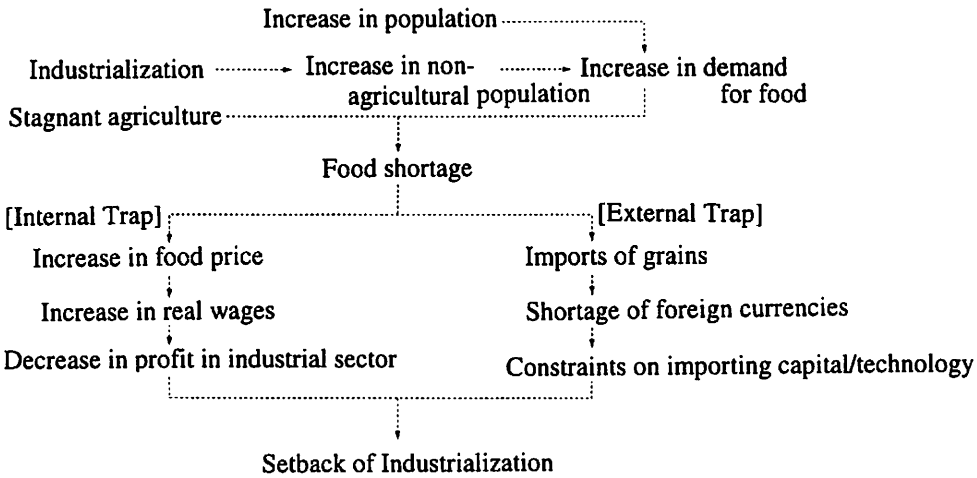
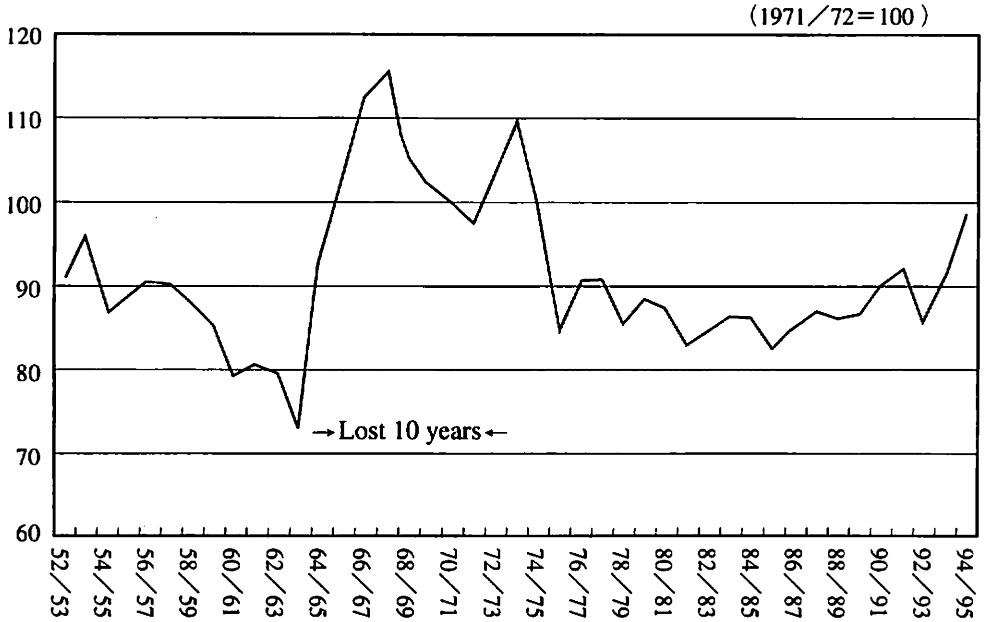
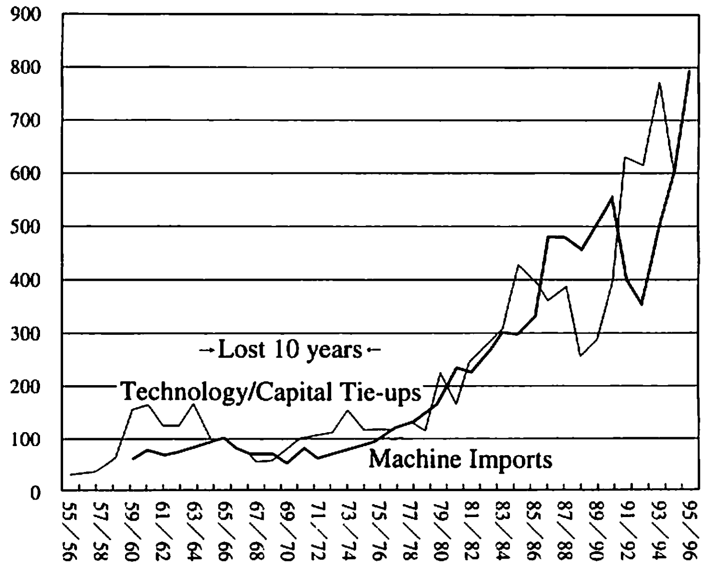


Figure 1-4 Transition of Terms of Trade between Agriculture and Industry



Source: Department of Agriculture of India

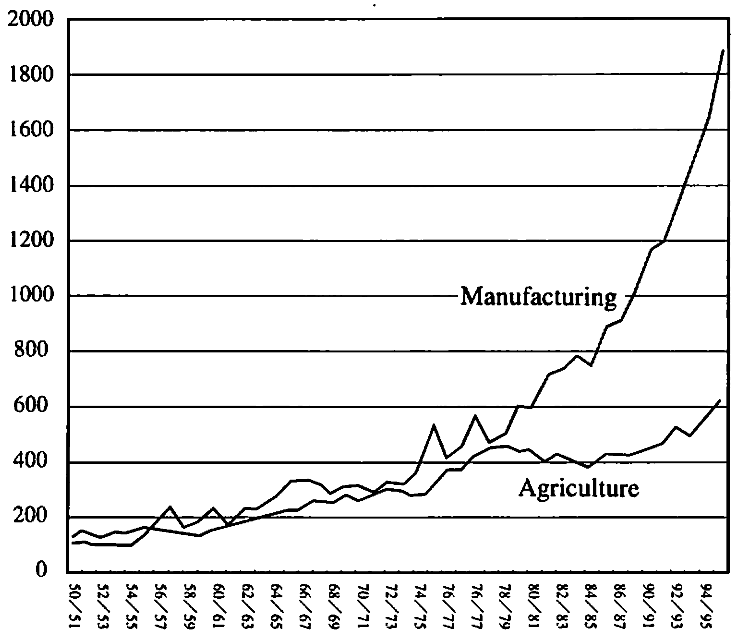
Figure 1-5 Machine Imports in US Dollars and Technology/ Capital Tie-up Approval Index (1965/66=100)



Source: Machine Imports: The same as those for Figure 2-1, but annual editions.
Number of technology/capital tie-ups: Economic Intelligence Service, Basic Statistics Relating to the Indian Economy, Vol.1.All India, 1989. However, the data from fiscal 1987/88 onwards is from Japan External Trade Organization, "JETRO White Paper, Volume of Investments, World and Japan's Overseas Direct Investments 1996".

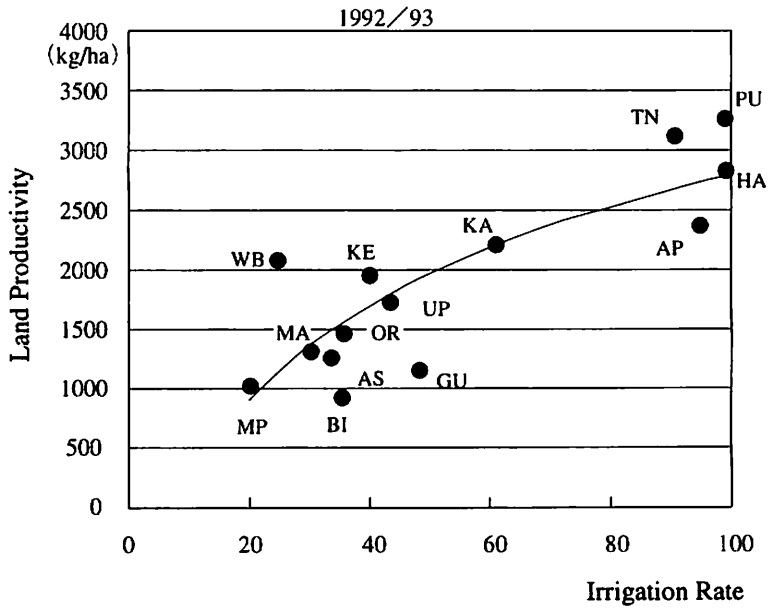
Figure 1-6 Transition of Real Capital Formation in Manufacturing and Agriculture

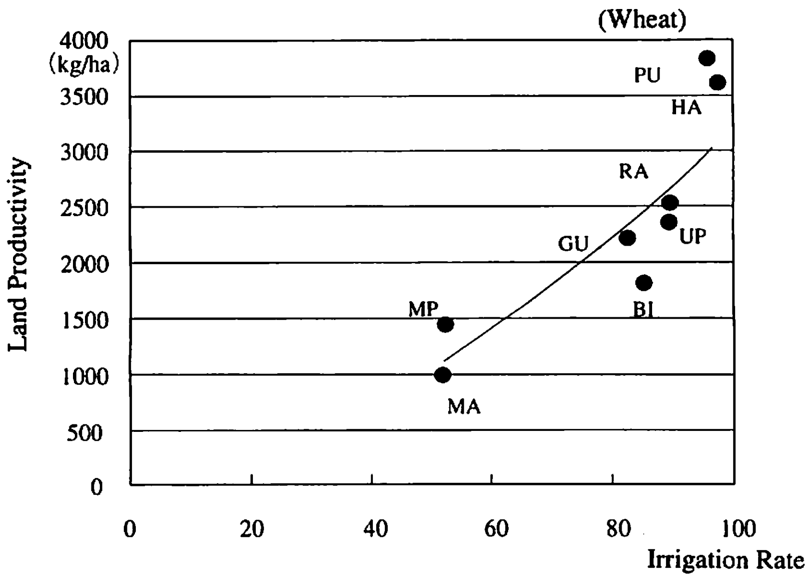
(unit: 100 million rupees based on the 1980/81 price)



Source: Government of India, Central Statistical Organization, National Accounts Statistics, annual issues.

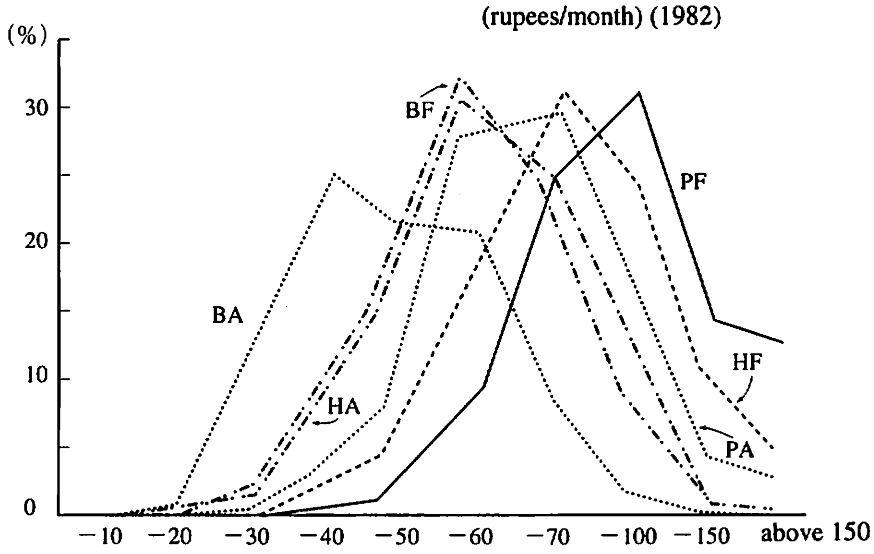
Figure 1-7 Irrigation Rate and Land Productivity (Rice)





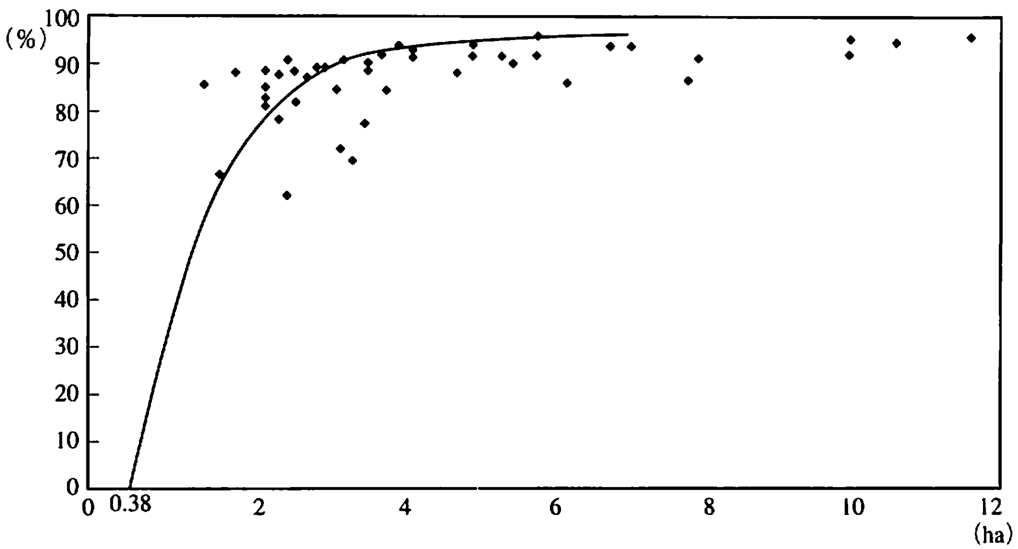
Note: For abbreviations of State names, see Table 2-3.
Source: Government of India, Ministry of Agriculture, Agricultural Statistics at a Glance, 1994.

Table 1-8 Par-capita Expenditures of Agricultural Households in Bihar



Note: P: Punjab, H: Haryana, B: Bihar
F: Landowner farmers, A: Agricultural laborers
Source: Calculated based on Department of Statistics, Ministry of Planning, Government of India, Sarvekshana, Vol.IV, No.1-2 July-October 1982.

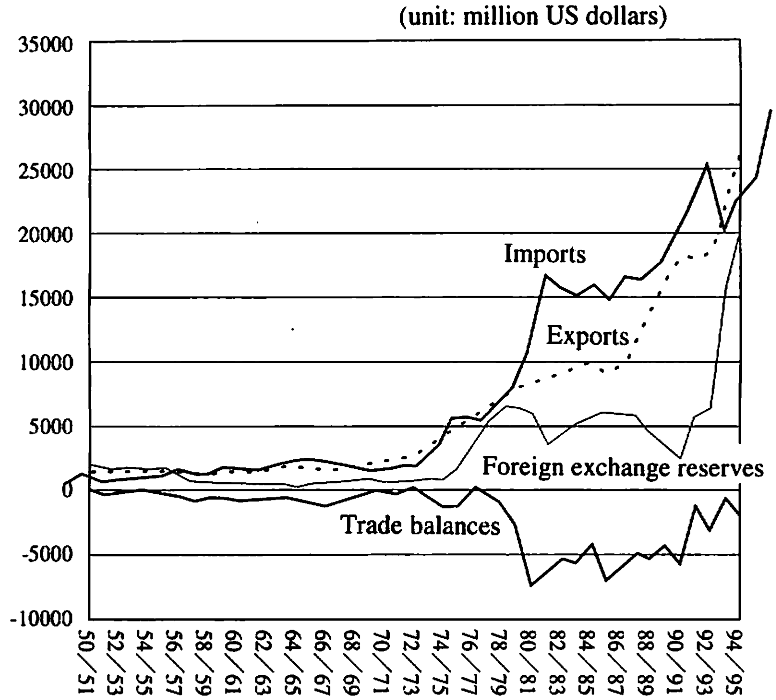
Figure 1-9 Rate of Marketable Wheat by Planted Area of Farming Household in Punjab



Note: The curve denotes estimated rates of marketable outputs obtained with the following conditions: annual wheat consumption per adult man: 165kgs; annual wheat consumption per household; 1,039kgs. Land productivity; 3,500kgs/ha; Average wheat-planted area (Rabi Period??): 80%. Therefore, marketable surplus is generated by an average farming household when the planted area is at least 0.38ha.

Source: Gov. of Punjab, Board of Economic Inquiry, Farm Account of Punjab 1988/89, & Family Budget of Punjab 1988/89.

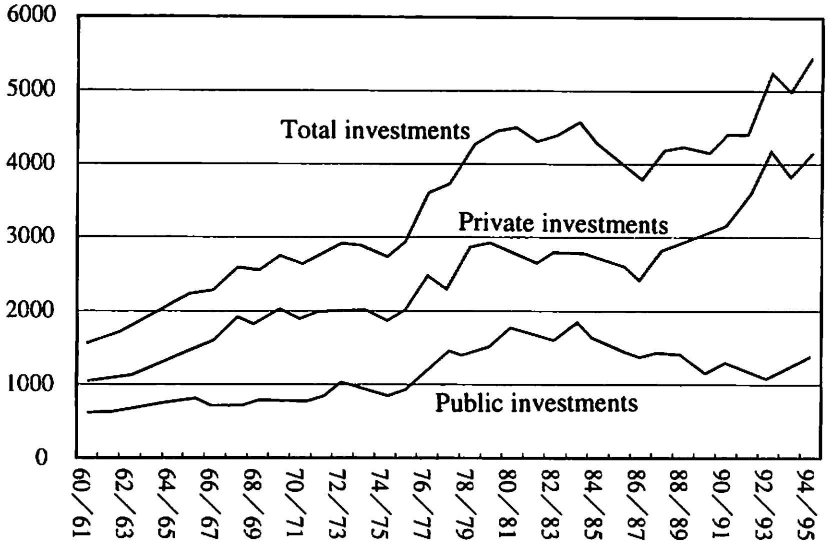
Figure 1-10 Exports, Imports, Trade Balances, and Foreign Exchange Reserves



Source: The same as for Table 2-1.

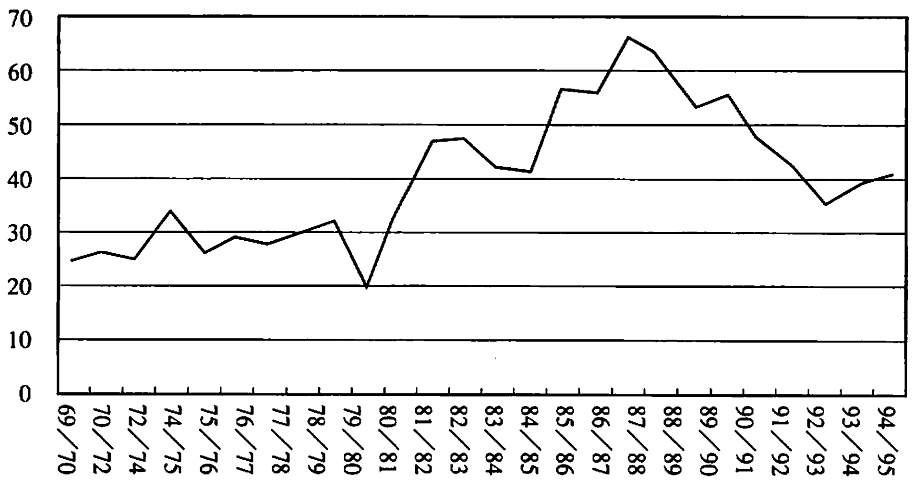
Figure 1-11 Transition of Real Fixed Capital Formation in Agricultural Sector

(unit: 10 million rupees based on the 1980/81 price)



Source: Government of India, Central Statistical Organization, National Accounts Statistics, annual issues.

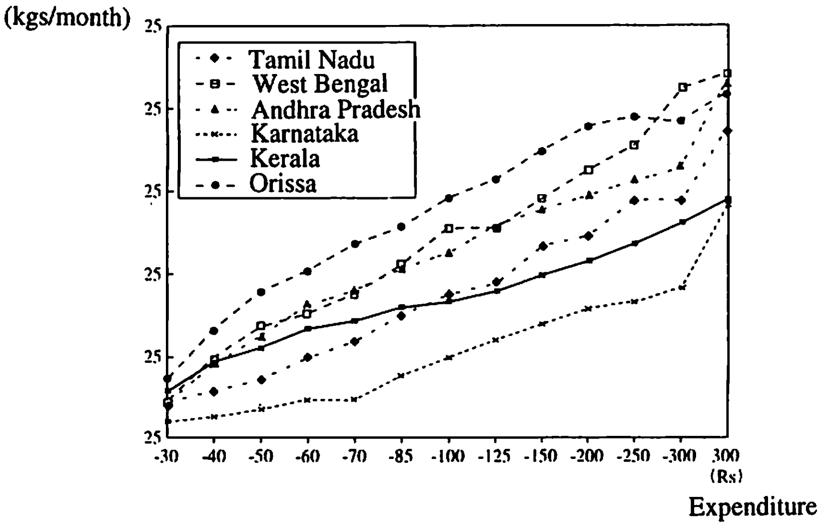
Figure 1-12 Ratio of Agricultural Credit Lines to Private Fixed Capital Formation



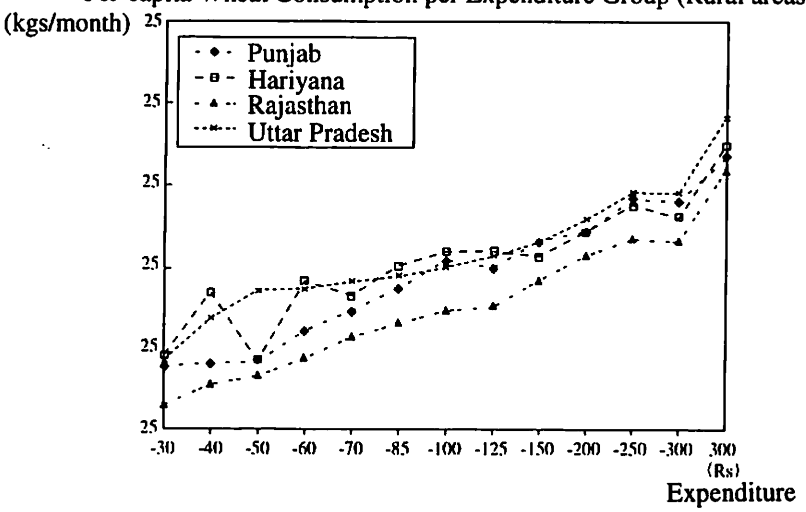
Reference: Agricultural Credit Lines: Reserve Bank of India, Report on Currency and Finance (Biennial issues).
Capital Formation: The same as for Figure 2-1.

Figure 1-13 Foodgrain Consumption by Expenditure Group

Per-capita Rice Consumption per Expenditure Group (Rural areas)



Per-capita Wheat Consumption per Expenditure Group (Rural areas)



Source: Based on Department of Statistics, Ministry of Planning, Sarvekshana, Vol X, No.2, 1989.

Chapter 4

Water Resources as a limiting Condition on World Population

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Introduction

The increase in the world population in the 21st century will be a critical constraining condition on improvement of our living standards, and, together with economic development, will make substantial impact on the resources and the environment of the Earth. The increase in the world population itself is, in turn, constrained by the resources and the environment. As T. R. Malthus predicted in the end of 18th century, the increase in population must be "checked" either in a positive way or in a preventive way at some point. Despite the fact that fresh water is essential for human life today as potable water, one of the indispensable resources for food production, or industrial water, the issue of water (shortage) has not been seen as a great constraining condition of resources, except in some countries in desert zones. However, the world population towards the 21st century will be nearly doubled in the coming fifty years, which will necessitate the increase in irrigation water for more food production and the rise in the demand for water for daily-life use and industrial use due to industrialization and urbanization. Thus, water is very likely to become a scarce resource in many countries. This essay will review future prospects for the populations in major regions, and discuss the extents to which water resources can be a constraint on population growth in those major regions of the world.

1. World Population Prospects

(1) Estimates of Future Population by United Nations

The world population will reach 6 billion next year. Although the population growth rate has been declining since hitting its peak, 2.04% per annum, in the period between 1965 and 1970, it is still as high as 1.37% per annum today (1995 – 2000). Especially, the growth rate in the developing countries, that account for 79% of the world population, is still 1.65% per annum. Some extremists say that even today's level of world population is no longer "sustainable" [1]in view of global environment including resources, energies, and food supplies, and that the Earth may face a catastrophe depending on how far the world population continues to expand.

According to the latest United Nations Population Projections (medium variant of the 1996 version)[2], the world population is estimated to reach 8 billion in 2025, 9.4 billion in 2050, 10.4 billion in 2100, and 10.8 billion in 2150 (See Table 1). The Club of Rome's second report forecast that the population would become stable at the level of 7.7 billion if the world birth rate reached the replacement level in 1990, and that the next century at least will see no catastrophe[3]. The world population based on the UN's medium variant, however, is observed to grow at a pace which exceeds The Club of Rome's "sustainable" level in about 2020.

Although the populations of developed countries are not expected to experience major changes, those of developing countries will likely grow further by 3.69 billion to 8.2 billion by 2050[4]. The absolute value of the population increase in Asia is relatively great; it is expected to rise by 2.0 billion, from 3.44 billion in 1995 to 5.44 billion in 2050. In particular, the populations of China and India, the world's most populous nations, will increase between 1995 and 2050, from 1.22 billion to 1.52 billion, and from 0.93 billion 1.53 billion respectively. Meanwhile, the relative population growth is the greatest in Africa, where the population will increase by 180%, from 0.72 billion to 2.05 billion during the same period, and will account for 21.8% of world population in 2050.

(2) Optimism about World Population

While the world population is expected to continue to grow substantially in the 21st century, the UN's biennial estimates in the 1990s have revised downwards their figures for the world population in 2025 and

2050 each time; from 8.50 billion and 10.02 billion (estimated in '92), to 8.28 billion and 95.8 billion (estimated in '94), to 8.04 billion and 9.37 billion (estimated in '96)[5]. It transpires that population growth and fertility (the major determinant of the former) in the developing countries have declined more than expected every year.

In the 1960s and 1970s, pessimism was dominant in future prospects for birth rates in developing countries. During those years, only a few small nations with advanced economic status were at the turning point of the fertility transition, so it was widely held that fertility transition could not occur without modernization. However, from the 1980s through the 1990s, fertility began to decline in many populous countries, including China, even though they lacked economic progress, and this tendency is "not an exception but the norm" in the developing countries[6]. The fertility started to decline even in the so-called extremely poor countries of South Asia or sub- Saharan Africa, and this demonstrates that well-managed family-planning programs, as well as social development programs (such as the elimination of poverty, expansion of primary health care, extension of basic education, improvement of women's status, etc.) can be promoting factors in reducing the birth rate.

2. Water Supply and Water Shortage

(1) Supply of Water

The total amount of water on the Earth is about 1.4 billion cubic kilometers (km^3), which consists of 96.5% of salty sea water, and only 2.53% (approx. 35 million km^3) of fresh water. Moreover, 69.6% of the fresh water on the Earth is locked in glaciers, etc., leaving only 30.1% (10.5 million km^3) underground and 0.34% (119,000 km^3) in rivers, lakes and marshes, etc[7].

Approximately 113,000 km^3 of water is supplied to the land area as rainfall by the water circulation system. Of this amount, 63.7% or 720,000 km^3 goes back to the atmosphere through evaporation and transpiration, and only 36.3% or 41,000 km^3 is left in rivers, lakes and marshes, or under ground. The total replaceable water resources per annum which can be used by human beings is 41,000 km^3.

The figures in columns (1) and (3) of Table 2 show regional water resources available. The proportions of utilizable fresh water in Africa, Asia, and Latin America, which consist mainly of developing countries, are 10%, 27% and 29% of the world's total respectively. If we compare this distribution with the distribution of the world population by region (Column (4) of Table 2), considerable gaps are found between the supply of and the potential demand (i.e., population) for water. The water supply in Asia is remarkably small compared to the population, and Europe (excepting Russia) and Africa also display this tendency more or less. On the other hand, the water supply in Oceania, South America, North America, and Russia is strikingly great (even relative to their respective population).

(2) Falkenmark's Measurement of "Water Shortage"

Falkenmark defines countries in the condition of "no water shortage" as those having 1,700m^3 (= ton) or more of utilizable amount of annually replaceable fresh water per capita; countries in the "water stress" condition, as those with 1,000 tons and above but less than 1,700 tons; and countries in the "water shortage" condition as those having under 1,000 ton[(8)].

Based on these definitions, the world or the major regions as a whole was in "no water shortage" condition in 1995 (Column (5) of Table 2). Reviewing the figures by country, however, there were eleven "water stressed" countries (270 million people), and 18 "water shortage" countries (166 million people), which make 4.7% and 2.9% of the world population respectively[(9)]. The majority of them are located in desert zones of the Middle East and Africa.

Although, despite the population growth, a water shortage of "the world" or "the major regions" is not expected at least until 2050, a near "water stress" condition is anticipated regionally in Africa and Asia as a whole in the latter half of the 21st century. Of the two world's populous nations, India will likely fall in the condition of "water stress" in the first quarter of the 21st century, and China also by 2050. By 2050, there will likely be 15 "water stressed" countries (2.3 billion people), and 39 "water shortage" countries (1.7 billion people), accounting for 24% and 28% of the world population respectively(10).

3. Maximum Allowable Population in view of Water Resources

(1) Cohen's Maximum Allowable World Population (in view of water resources)

Cohen calculated the number of human beings sustainable by the utilizable replaceable fresh water per annum on the Earth, on the assumption that the use of water is restricted to minimum daily-life requirements such as drinking and irrigation for production of grains(11). His computation is as follows.

First, 2kgs of wheat is required to produce 1kg of flour. Assuming the transpiration rate is 500%, 1,000kgs of water is needed (= 2kgs x 500 = $1m^3$ = 1 ton). One kilogram of flour generates a energy value of 3,500 Kcal. If a person consumes 1,000kcal a day, the amount of fresh water to produce wheat that can supply the required energy for a year is, therefore, 100 ton.

The amount of fresh water needed for a person to take in the necessary amount of energy for a year from grains produced by irrigation agriculture (Wr m^3) can be obtained by the following equation.

$$Wr = \frac{D}{[10 \times U \times (1-L)]}$$

where,

D = Energy (kcal) required by a person for his activity per day

10 = The coefficient to denote that 100 ton of water generates 1,000kcal of energy per capita per day.

U = A consumption rate of utilizable replaceable fresh water per annum (%)

L = A rate of grain lost in the processes after production and before consumption

In this equation, the amount of water to produce grains that can generate energy required by a person for daily activities for a year (X = D kcal/ [(1,000 kcal/ day/per capita per year)/ 100t per capita per year]) is obtained first. Then, based on the person's consumption rate of fresh water (U), the required amount of water (X/U) is calculated. Lastly, taking into account the loss of grains (L), the required amount of water [(X/U)/(1-L)] is obtained.

Thus, by adding the amount of fresh water required for domestic use ($37m^3$)[12] to the obtained value of Wr, the amount of fresh water needed for a person for food and daily life for a year is obtained. Finally, the maximum allowable population under a particular condition of water resources is obtained as:

$$P\max = \frac{Wa}{(Wr + 37)}$$

where Wa = An amount of replaceable fresh water human beings can utilize.

Cohen calculates the maximum allowable populations on combinations of the following assumptions.

① U is either 20% (a relatively realistic level)[13] or 100% (the greatest maximum value available but an unrealistic level).

② D is either 2,350kcal (the average intake of energy)[14] or 10,000kcal (the average consumption in the US)

③ L is either 10% (quite efficient but unrealistic) or 40% (the world average level)

④ Wa is $41{,}000km^3$ (the total amount the world's utilizable fresh water), 14,000 km^3 (the estimated ceiling of the amount of fresh water actually used), or 9,000 km^3 (the estimated floor value of the same)

The maximum allowable population in the case of the greatest water consumption (U=20%, D=10,000kcal, and L=40%) is, therefore, 4.9 billion, 1,7 billion or 1,1 billion depending on the value of Wa. Needless to say, the actual world population is far above any of these figures. This implies that it is almost impossible, in view of the water resources, for all the countries in the world to enjoy as luxurious dietary lives as the US of today. On the other hand, in the condition of the least water consumption (U = 100%, D = 2,350kcal and L = 20%), the Pmax value is 137.5 billion, 47 billion or 30.2 billion depending on the value of Wa. However, it is impossible to use 100% of utilizable fresh water, and these figures are so unrealistic that the [realistic] maximum allowable world population would, of course, be much below them.

In the standard condition which can be considered relatively close to the current situation of the world's water consumption (i.e., U = 20%, D = 2,350kcal, and L = 40%), the Pmax value is 20.5 billion, 7 billion or 4.7 billion. As far as the condition of water resources is concerned, the maximum allowable level of the world population is not specially high, which implies that the world as a whole may face tight constraints in the 21st century, depending on efficiency in use of water resources.

(2) Maximum Allowable Populations of Major Regions in the "standard condition" and the "75% efficiency-improvement condition"

Column (2) of Table 3 shows the maximum allowable populations of the world major regions, obtained by the above Cohen equation where U = 20%, D = 2,350kcal, L = 40% and Wa = an utilizable amount of replaceable fresh water per annum (41,000 km^3 if for the world as a whole).

If we compare the maximum allowable population in regions in the "standard condition" with the present and future populations (Column (1) of

Table 4), the 1995 populations in all the regions are below the maximum allowable level. In 2050, however, the total Asian population will be 5.54 billion, exceeding its allowable maximum (5.40 billion), and that in Africa will be 2.05 billion, approaching its allowable maximum (2.101 billion). As for the world's two most populous nations, the population of India in 1995 is already equivalent to the maximum allowable (0.93 billion) and is expected to exceed the maximum allowable level by 600 million , and that of China will also exceed the maximum allowable level (1.40 billion) even before 2025, and will be in excess of it by 120 million in 2050.

In Cohen's equation, both U and L represent utilization-efficiency rates of water resources. Column (3) of Table 3 (Condition 2) and Column (2) of Table 4 show the maximum allowable populations obtained by the same calculation but with the assumption that the combined efficiency, U(1-L) has been improved by 75% (Condition with 75% improved efficiency). By this assumption, the maximum allowable populations of the world and of the major regions are 72% greater than those in the "standard condition", and both of the populations of Asia (including China and India) and Africa will be below the maximum allowable level throughout the 21st century.

(3) Assumption: 20% of energy intake is from meat.

Intake of 1kcal of energy from meat requires ten times the amount of plants (i.e., land and water as well) needed to take in 1kcal from grains. If the proportion of meat increases, therefore, the "water stress" becomes greater. Assuming that 20% of 2,350kcal is obtained from meat, the constant of the Cohen equation, 10, is reduced to 8.2 (= 10 x 0.8 + 1 x 0.2). The maximum allowable populations in the "standard condition" and "75% improved condition" corrected by this new coefficient are shown in Columns (4) and (5) of Table 3, and Columns (3) and (4) of Table 4.

In the corrected "standard condition" (20% taken from meat), the maximum allowable world population is 16.9 billion, and estimated future populations are below this level in 2050, and even 2150 (10.8 billion).

However, the Asian population will exceed its maximum allowable level (4.5 billion) as early as 2025, and the African population will also exceed its maximum allowable level (1.7 billion) in 2030. In 2050, the populations in Asia and Africa will exceed their maximum allowable level by 990 million and 320 million respectively. The 1995 populations of two most populous nations (China and India) are already above their maximum allowable levels (1,150 million and 760 million respectively).

In the meantime, if assuming that the water utilization rate is 75% greater (with 20% energy still taken from meat) than the standard condition, neither of the future populations in Asia and Africa exceeds their maximum allowable level (7.7 billion and 3.0 billion respectively). As for the two most populous nations, China's population will not exceed its maximum allowable level, but India's population will exceed its maximum allowable level (1.32 billion) in 2025, and the excess will reach 210 million in 2050.

Conclusion

Even in the 21st century, water resources and food supplies are unlikely to be limiting conditions on populations in Oceania, North America, and Europe, which are largely developed regions, or in South America, mainly a developing region – on the whole, and apart from partial variations.

In those regions, water resources are more than sufficient even under quite severe conditions (Condition 3 of Table 3). In South America, let alone the developed regions, water shortage are unlikely to occur even after taking into account the increase in demand for water to be caused by its further industrialization, urbanization, and improvement of living standards.

However, in Asia and Africa, where the populations together make up three quarters of the world total, and will exceed 80% of the same in the 21st century, securing water resources will be the major political issue for governments. Especially in Asia, many West Asian nations are already in the "water stress" condition. Whereas some countries are attempting improvements by desalination of sea water or other methods, the water shortage in the world's two most populous nations, India and China (together accounting for 38% of the world population) will hamper their efforts for more food production and industrial development. Moreover, their water shortage could exert considerable influence upon the world food situation through demand in the international grain market[16]

Both China and India have adopted the market economy system in an attempt to improve their living standards, and are trying to promote rapid economic development. In the process, however, the two countries run the risk of falling abruptly into the conditions of water stress or water shortage, due to the population growth and the improved living standards associated with increases in demand for food, as well as industrialization and urbanization associated with increases in demand for industrial and daily-life water. Both countries will need to make political efforts, in planning future development strategies, to enhance their water-intake efficiency by constructing more dams and canals, etc., convert their agriculture or industry to the systems with higher efficiency of water consumption, and to prevent water contamination, and so forth.

Note

(1) Ehlich, P.R.et al., The population Explosion, Simon and Schester, 1990.

(2) United Nations, World Population Projections to 2150, ESA/P/WP.145, 1998.

(3) Meadows, D.H. et al., Beyond the Limits, Chelsea Green, 1992.

(4) United Nations, World Population Prospects: The 1996 Revision, Annex I: Demographic Indicators, 1996.

(5) United Nations,World Population Prospects: The 1992 Revision, 1993;

United Nations, World Population Prospects: The 1994 Revisions, 1995.

(6) Cleland, J., "A Regional Review of Fertility Trends in Developing Countries: 1960 to 1995," in W. Lutz (ed.), The Future Population of the World (rev. ed.), IIASA, 1996, pp,47-72.

(7) World Resource Institute, World Resources 1994–95, Oxford University Press, 1994; Shiklomanov, I.A., "World Fresh Water Resources," in P.H., Gleick (ed.) Water in Crisis, Oxford U.P., 1993.

(8) Falkenmark,Malin, "Rapid Population Growth and Water Scarcity: The Predicament of Tomorrow's Africa," in K. Davis et al. (eds.), Resources, Environment, and Population: Present Knowledge, Future Options, Oxford U.P., 1991, pp. 33-56; Falkenmark, Malin et al., Population and Water Resources: A Delicate Balance, Population Bulletin, Population Reference Bureau, 1992.

(9) Outlaw, Tom G., et al., "Water Forever: Future of Population and Replaceable Water Supply – Revised Data", Population Action International, 1998. In the meantime, note that $1km^3$ (cubic kilometers) = 1 billion m^3 (cubic meters = ton).

(10) Outlaw, Tom G., et al. (ibid)

(11) Cohen, Joel E., How Many People Can the Earth Support? W. W. Norton, 1995, Chapt. 14.

(12) Falkenmark suggests that even a country inclined to water shortage should secure at least 100 liters (= 0.1kg = $0.1.m^3$) of water per capita per day for daily-life use including drinking and hand-washing. With this, the annual requirement becomes $0.1m^3$ x 365 days = $36.5m^3$. Falkenmark 1992 (ibid).

(13) Of $41{,}000km^3$ of utilizable amount of annual world replaceable fresh water, the stable replaceable amount of water supply is $14{,}600km^3$, of which $12{,}500km^3$ is said to be usable in residential areas. Of the latter, 35% or $4{,}430km^3$ is estimated to be actually used for irrigation, industries, and daily life. Sandra Postel's "Politics of Scarcity –

Dividing the Waters", Worldwatch Papers 132, 1996.

Consumption Rates (U) computed based on the above figures are 30.5% for 12,500km^3 and 10.8% for 4,430km^3 against the utilizable amount of fresh water 41,000km^3. Accordingly, U = 20% is not a very unrealistic value.

(14) Kates, R.W. et al., The Hunger Report: Update 1989, A.S.F. World Hunger Program, Brown University, 1989.

(15) Brown, Lester R. et al., Chinese Water Shortage Could Shake World Food Security, World-Watch Institute, 1998.

Table 1 Population Trends of the World and by Major Region

(unit: million)

	1950	1970	1995	2025	2050	2100	2150
World	2,524	3,702	5,687	8,039	9,367	10,414	10,806
Developed Regions	813	1,008	1,171	1,220	1,162	-	-
Developing Regions	1,711	2,694	4,516	6,819	8,205	-	-
Africa	224	364	719	1,454	2,046	2,646	2,770
Asia	1,402	2,147	3,438	4,785	5,443	5,850	6,060
China	555	831	1,220	1,480	1,517	1,535	1,596
India	358	555	929	1,330	1,533	1,617	1,669
Latin America and Caribbean Islands	166	284	477	690	810	889	916
North America	172	231	297	369	384	401	414
Europe	547	656	728	701	638	579	595
Other than Russia	445	526	580	570	523	-	-
Russia	102	130	148	131	114	-	-
Oceania	13	19	28	41	46	49	51

Note: United Nations, World Population Prospects: The 1996 Revision, 1996. United Nations, World Population Projections to 2150, 1998.

Table 2 "Utilizable Amount of Annual Replaceable Fresh Water", "Population" and "Per-Capita Amount of Fresh Water" of the World and by Major Region

Region	(1) Fresh Water (km^3)	(2) 1995 Population (million)	(3) Proportion of Fresh Water (%)	(4) Proportion of Population (%)	(5) Per-capita Fresh Water (1000m^3) 1995	(6) 2025	(7) 2050
World	40,673.0	5,687.1	100.0	100.0	7.2	5.06	4.34
Africa	4,184.0	719.5	10.3	12.7	5.8	2.88	2.04
Asia	10,781.0	3,437.8	26.5	60.4	3.1	2.25	1.98
China	2,800.0	1,220.2	6.9	21.5	2.3	1.89	1.37
India	1,850.0	929.0	4.5	16.3	2.0	1.39	1.21
Latin America and Caribbean Islands	11,943.0	476.6	29.4	8.4	25.1	17.31	14.70
North America	5,379.0	296.6	13.2	5.2	18.1	14.58	14.01
Europe	6,438.0	728.2	15.8	12.8	8.8	9.18	10.09
Other than Russia	2,395.0	579.7	5.9	10.2	4.1	4.20	4.60
Russia	4,043.0	148.5	9.9	2.6	27.2	30.86	34.56
Oceania	2,011.0	28.3	4.9	0.5	71.1	49.05	43.71

Note: The amounts of fresh water are assumed to be unchanged from 1995 through 2050.

(Reference) Populations are based on the reference used for Table 1. The amounts of fresh water are from World Resource Institute, World Resources 1994-95, Oxford University Press, 1994.

Table 3 Maximum Allowable Populations (Pmax) of the World and by Major Region in view of Water Resources

(Unit of Population: 100 million)

	(1) Wa (km^3)	(2) Pmax (Condition 1)	(3) Pmax (Condition 2)	(4) Pmax (Meat 20%) (Condition 3)	(5) Pmax (Meat 20%) (Condition 4)
World	41,000	205.5	354.7	169.1	292.6
Africa	4,184	21.0	36.2	17.3	29.9
Asia	10,781	54.0	93.3	44.5	76.9
China	2,800	14.0	24.2	11.5	20.0
India	1,850	9.3	16.0	7.6	13.2
Latin America and Caribbean Islands	11,943	59.9	103.3	49.2	85.2
North America	5,379	27.0	46.5	22.2	38.4
Europe	6,438	32.3	55.7	26.5	46.0
Other than Russia	2,395	12.0	20.7	9.9	17.9
Russia	4,043	20.3	35.0	16.7	28.9
Oceania	2,011	10.1	17.4	8.3	14.4

Note: Wa = Utilizable amount of Annual Replaceable Fresh Water (in km^3). Condition 1 is "Standard condition", Condition 2 is "Condition of 75% improvement in utilization of water", Condition 3 (of Column (4)) and Condition 4 (of Column (5)) are the Grain-Meat ratio of 80% to 20% added to Conditions 1 and 2 respectively.

Table 4 Differences between Maximum Allowable Populations by Condition in view of Water Resources and Current Population (1995)/Future Population Estimates (2050)

(Unit of Population: 100 million)

	(1) (Pmax(1)-P)		(2) (Pmax(2)-P)		(3) (Pmax(3)-P)		(4) (Pmax(4)-P)	
	1995	2050	1995	2050	1995	2050	1995	2050
World	148.6	11.8	297.8	261.0	112.2	75.4	235.7	198.9
Africa	13.8	0.5	29.0	15.7	10.1	-3.2	22.7	9.4
Asia	19.6	-0.4	58.9	38.9	10.1	-9.9	425.0	22.5
China	1.8	-1.2	12.0	9.0	-0.7	-3.7	7.8	4.8
India	0.0	-6.0	6.7	0.7	-1.7	-7.7	3.9	-2.1
Latin America and Caribbean Islands	55.1	51.8	98.5	95.2	44.4	41.1	80.4	77.1
North America	24.0	23.2	43.5	42.7	19.9	18.4	35.4	34.6
Europe	25.0	25.9	48.4	49.3	18.7	20.1	38.7	39.6
Other than Russia	6.2	6.8	14.9	15.5	4.1	4.7	12.1	12.7
Russia	18.8	19.2	33.7	33.9	15.2	15.6	27.4	27.8
Oceania	8.6	9.6	17.0	16.9	8.0	7.8	14.1	13.9

Note: Pmax(1) to (4) are Pmax in Conditions 1 to 4, respectively.

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