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著者	ZHANG Jiacheng
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Jiacheng ZHANG

Chinese Academy of Meteorological Science, Beijing, China

The impact of climate on socioeconomy is a very complicated problem, influenced not only by interactions in the climate system between the atmosphere, oceans, continents, cryosphere and biosphere, but also by a series of socioeconomical factors, such as the level of development, technology and science, and the political and psychological situation, etc. In other words, a climate impact system does exist and may be illustrated by Fig. 1. In this system climate change only plays a trigger role. The impact is really a process of modification and transmission of influence among the constituent parts of this huge system. However, two or more impacts are possible in an interacting or overlapping fashion (Zhang 1976, and 1988).

This article does not focus solely on the climate impact system, it also deals with several problems regarding the vulnerability of socioeconomical development and climate change in China, which would serve as examples for tackling the mechanisms of the system.

UNIT CLIMATE CHANGE AND ITS IMPACT

For agro-climatic studies in China the most widely used climatic parameters are precipitation, accumulated temperature $\geq 0°C$ and $\geq 10°C$, total annual solar radiation etc. According to Zhu Kezhen (1963) and others, photosynthetic energy is very abundant throughout the country. If utilization efficiency reaches 5% cereal production per hectare will be about 32 tons in southern China, and 36 tons in northern China, much higher than present yield levels. Therefore the impact of radiation variation for agricultural production is not essential in this discussion. On the contrary, temperature and precipitation are highly variable in general, and hardly sufficient for normal agricultural production. Their variations frequently cause serious climatic calamities, such as droughts, floods, frost damage, etc., and these two parameters are most important in a climate impact study of China.

Table 1 shows the thermal condition requirements, for some major cultural crops related to different varieties and maturities. It may be seen that the region where accumulated temperature $\geq 10°C$ is below 1500°C is not suitable for agricultural production. Only in those regions where the accumulated temperature exceeds 4000°C is double cropping possible. Triple cropping is possible only in regions were the accumulated

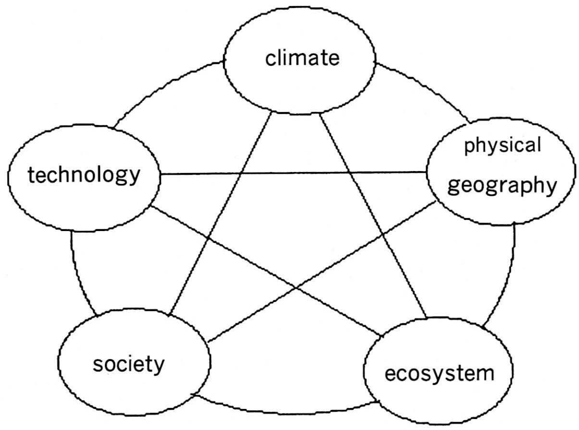

Fig. 1. Climate impact system.

Table 1. Accumulated temperature required by some major crops in China and their growing period

crop	early-maturing variety		mid-maturing variey		late-maturing variey	
	days	°C	days	°C	days	°C
early rice *	<75	<1800	80–90	1800–2000	>90	>2000
late rice *	<90	<2000	90–100	2200–2400	>100	>2400
spring wheat **	<100	<1600	100–120	1600–1900	>120	>1900
corn	<100	<2200	100–120	2200–2600	>120	>2600
cotton	<150	<3500	150–170	3500–3900	>170	>3900

* from transplanting to harvest

** The accumulated temperature and growing period refers to ≥10°C, except winter wheat which refers to ≥0°C.

temperature is ≥5800°C. The higher the crop yield, the greater acumulated temperature and longer growing period is required (Zhang 1981).

It is suggested that when annual temperature has a 1°C variation the mean daily temperature for every day in the year would also change by 1°C, then the increase of accumulated temperature of ≥10°C would be equal to the number of days ≥10°C, with an insignificant error smaller than 10–20 days.

From Table 1 the difference between required accumulated temperature for early maturing varieties and late ones is about 200–400°C, equivalent to 100–200°C difference for a change of grade variety (e.g. from an early-maturing variety to a mid-maturing variety, or from a mid-maturing variety to a late-maturing variety). In southern China (a three cropping region) the change of accumulated temperature, in the case of a 1°C change in annual temperature, is about 365°C, and the northern part of China (a one croping region) it would reach 150°C or more (Fig. 2, and Fig. 3).

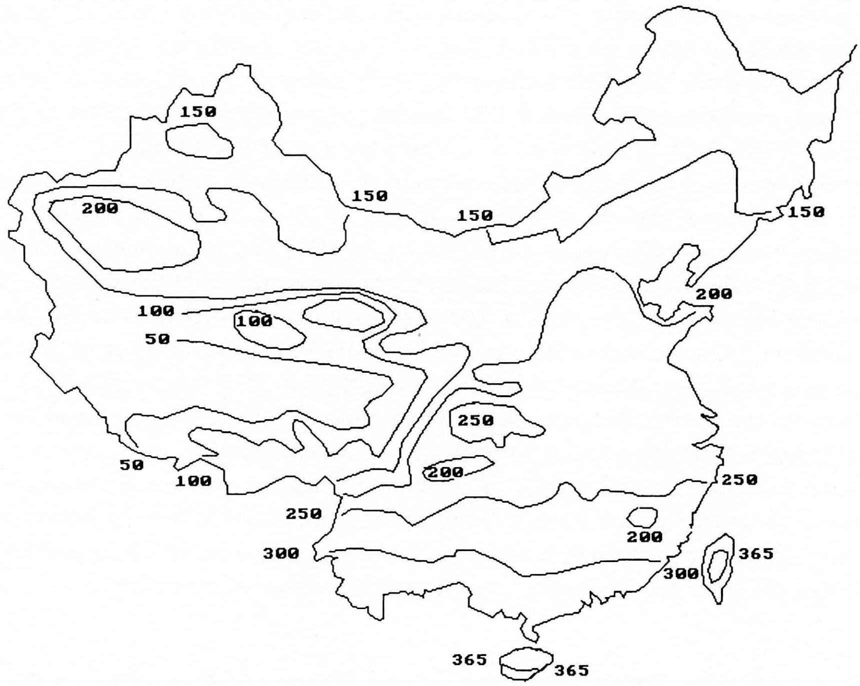

Fig. 2. Duration of days $\geq 10°C$ in China.

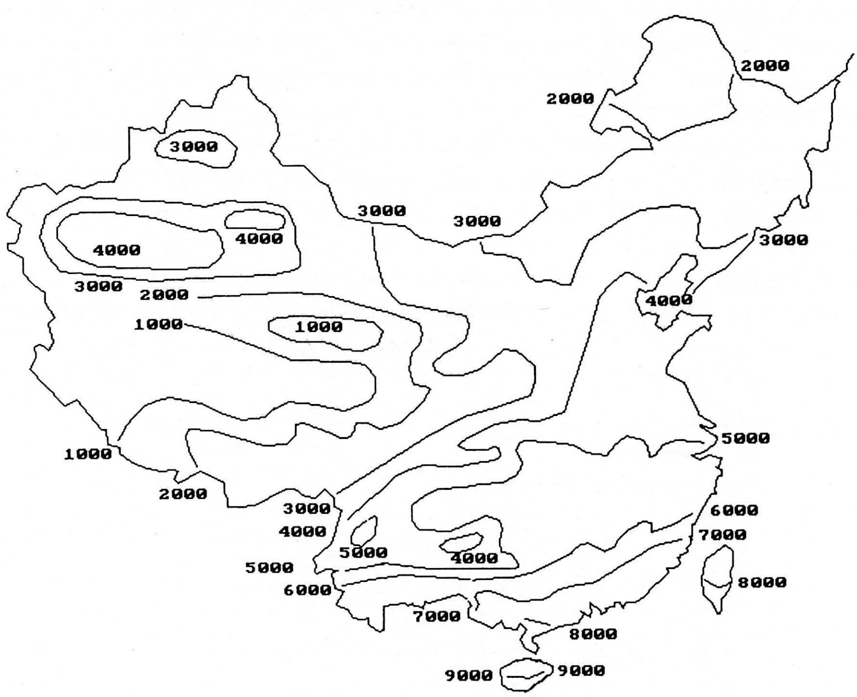

Fig. 3. Accumulated temperature $>10°C$ in China.

These amounts of accumulated temperature change are large enough to bring about a maturity grade change in all crops throughout China. Experience from agricultural production indicates that such a change in grade maturity could cause about a 10% variation in yield potential. Thus a 1 °C change in temperature might lead to a variation in yield of about 40 billion kg at China's present production level.

For every one mm variation of precipitation the change of productive potential per hectare of farmland may be roughly estimated as 10 kg for cereal products, if the evapotranspiration coefficient is supposed to be 500. Since the evapotranspiration coefficient for different crops is not the same, the precipitation potential for a specific crop should be revised by the ratio of its evapotranspiration coefficient to 500. As mentioned above, the estimated change in yield potential might reach about 1,000 kg per hectare as a result of a 100 mm variation in precipitation. It is worth noticing that this analysis refers to water deficient regions, where the aridity index is over 1 and the shortage of water is a limiting factor in agricultural development.

It is convenient to take $\Delta T = 1\,°C$, $\Delta R = 100$ mm as an unit of climate change, not only because these two values have a definite meaning in agricultural production, but since they are also the amplitudes of temperature and precipitation change which have been observed from the beginning of instrumental observation in China.

WATER BALANCE IN THE NATURE-MAN SYSTEM (NMS)

For assessing socioeconomical vulnerability to the precipitation shortage as well as for droughts and floods, it is necessary to study water balance in the Nature-Man System which consists of three important subsystems whose interactions are shown in Fig. 4 (Zhang 1988).

The first subsystem is natural precipitation which is unique water input on the land surface. However, owing to its very strong 'impulsiveness' and distributional extremes it proves difficult to satisfy directly and continuously the water requirements of the ecosystem and human life.

The second is the water resources formation and classification subsystem of the Earth's surface and underground. However, its function as a portion of precipitation

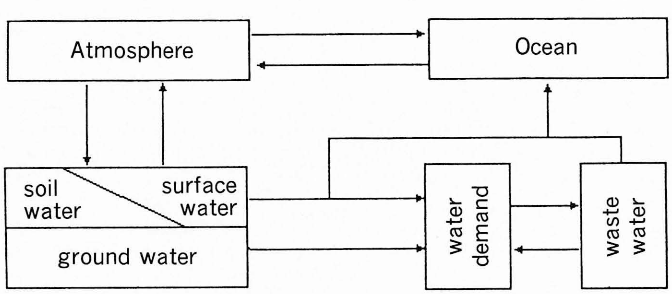

Fig. 4. Water balance in Nature-Man System (NMS).

transforms into four types of water resources (Zhang 1991). The first water resource (W_1), or simple water resource, consists of runoff and ground water as defined by hydrological statistics in China; the second water resource (W_2), or soil water, generally is not involved in hydrological statistics but is vitally important to the wild ecosystem and rainfed agriculture; the third water resource (W_3), or evaporation, can be transformed into a water resource through artificial conservation and also remains in soil. So W_3 may be considered as part of W_2; the fourth water resource (W_4) is the exchange of runoff among regions, though for a whole river basin it can be omitted.

Water demand consists of three constituent parts which are different in character and magnitude, namely: daily life water demand (D_1), industrial water demand (D_2) and agricultural irrigation water (D_3). So we have the following critical condition:

$$\sum_{i=1}^{5} W_i + W' \geq \sum_{j=1}^{3} D_j \quad (1)$$

W' is the water stored in reservoirs or underground. The mean value of W' for a long period of years would be zero.

Agriculture is the only production field where W_2 is available. The shortage of water resources would be apparently relaxed, if W_2 could be fully used in agricultural production in which W_1 or other water resources are only used as a supplement. Thus the following equation may be established.

$$W_b \geq D_1 + D_2 + (F_m - W_2 U_{22})/U_{21} \quad (2)$$

$W_b = W_1 + W_4 + W_5 + W'$ is the first water resource in a broad sense, consisting of all water resources which could be collected, transmitted and distributed to satisfy any of the water demands of human society.

r is the repetivity of water use in industry. Repetivity is the major factor in making water demand much smaller than water consumption by a factor $\frac{1}{1-r}$.

U is the economical water equivalent (output/water). U_1 is this parameter for industry, and U_2 for agriculture. U_{21} is the parameter of the first water resource in a broad sense for agriculture, and U_{22} for the second water resource.

Fm is the requirement of agricultural products in the discussed region, and $Fm_2 = W_2 U_{22}$ is the part of Fm produced at the cost of W_2. The third term in right side of equation (2) is the demand of agriculture to W_b.

It is very difficult to collect multilateral data for all the parameters in equations (1) or (2) for any region, even for a few years, due to diversified purposes, methodology and organizaton in data processing adopted by the different responsible agencies. Only for the two dry years of 1980 and 1984 in Beijing is the data more on less perfect enough to satisfy the requirement of equations (1) and (2). This is analysed in Table 2, and the result indicates that, with a considerable supplement W' from water reservoirs, in these two years, the demand and supply of water is just in balance.

In successfuly dealing with the droughts of 1980 and 1984 it was not only through the effective use of water reservoirs, but also because water saving technology played an important role. Table 3 shows the improvement in the water situation for industry (from *Science and Technology Daily*, China, June 29, 1991).

In agriculture the water demand for Beijing in the 1980s is about 4.2×10^8 t smaller

Table 2. Water budget of Beijing in 1980 and 1984 (10^8 t)

	supply		demand		
	1980	1984		1980	1984
W_1	17.31	21.61	D_1	4.26	6.27
W_4	10.53	7.55	D_2	8.49	5.64
W_5	0.69	0.67	D_3	26.12	22.15
W'	12.2	3.28	ΣD	38.87	34.06
W_b	40.73	33.11	$W_b - \Sigma D$	1.96	−0.95

Table 3. Some parameters of water use in Beijing

parameters	1981	1990
industrial output (10^8 yuan)	228.6	469
Water need (10^8 t)	8.49	5.64
repetivity (%)	48.57	74.1

than the 1970s average.

Owing to the varibility of all the parameters not only do equations (1) and (2) reflect a dynamic balance, they also express the static relation between water and socioeconomy in the rather short period of several years.

All the parameters except W_2, in equation (1) may be found in statistical year books. Until now there are no regular or precise records of W_2 owing to the difficulty in observing soil moisture. In recent years Pei Buxiang and Mao Fei have collected soil moisture data series, and calulated the soil water contained in a 100 cm soil layer (in mm). The calculations are static values. But W_2 is a dynamic value because of its incessant consumption through evaporation, and supply through precipitation and groundwater capillary effect. However, even these dynamic processes are far from clear, not to say the collection of data necessary for investigation. So in this article it is only possible to use indicated soil water in a 200 cm layer as a first approximation. In Table 4 effective soil water is defined as soil water minus withering soil water (a little less than 10 mm) below which water cannot be taken up by plants.

If it is considered that 1 mm is equivalent to 10 tonnes of soil water in a 100 cm soil layer per hactare, as mentioned above that could have potential cereal production of about 10 kg/ha. Consequently if this layer held 137.5 mm of water, then there would be an yield potential of about 1375 kg/ha. However, soil water available to crop plants, as well as wild vegetation, is not limited to a 100 cm layer, it can reach to at least a 200 cm layer or even deeper. For example, experiments on Weibei highland, Shaaxi Province, show that, if appropriate fertilizers are used winter wheat can lay roots over 200 cm deep. Statistics show in general that a 200 cm soil layer contains water double that in a 100 cm layer. Therefore the potential of cereal production per

Table 4. The effective soil water in a 100 cm layer and precipitation (mm) at Miyun station in Beijing

	1979	1980	1981	1982	1983	1984	1985	1986	1987
S.W 100 cm		154	129	127	132	116	144	144	141
Precipitation	719	383	393	545	491	489	724	666	684
	1988	1989	mean						
S.W 100 cm	142	147	137.5						
Precipitation	673	444	565						

Table 5. Irrigational experiments of MWC for winter wheat, 1983–1986.

irrigations	0	1	2	3	4	5	6
mean yield (t/ha)	2.910	3.885	4.470	4.770	4.926	4.770	4.755
marginal yield (t/ha)		1.035	0.585	0.300	0.150	−0.030	−0.024
marginal effec. (kg/t)		1.38	0.76	0.40	0.20	−0.04	−0.032

hectare would be 2.75 tonnes.

The Ministry of Water Conservancy conducted irrigational experiments between 1983 and 1986 for winter wheat. The results are shown in Table 5.

The mean values for the five experiment sites show that, without any irrigation, the yield of winter wheat is about 2.910 t/ha. That is quite near to the yield of winter wheat growing only on the effective soil water (2.75 t/ha).

Furthermore the marginal yield and efficiency drop quickly as irrigation increases. Therefore it is irrational in water deficient regions to develop agriculture that is simply dependent on the extension of irrigation.

Now the third term of equation (2) will be discussed. This term consists of two important parameters (W_2, and Fm) and connects W_2 with other water resources through its explicit requirements towards agricultural products. Now it is necessary to give an estimation of Fm.

Fm has no fixed value because agricultural products or grain products vary strongly with socioeconomical development. The present level of agricultural production in China is still rather low, and may be taken as the minimum requirement of agricultural production. Besides, Fm may also be estimated by planning. For example, Beijing could produce 5 million tons of grain, if 500 kg of grain per capita is projected. Since, any value may be given to Fm according to the level of development. Then with the given value, the water balance could be readjusted.

Furthermore rainfed agriculture is only maintained by W_2, and thus gives a parameter to separate the effect of W_1 and W_2 from the total. Table 6 shows some parameters for grain production in Beijing in 1980 and 1984. The same parameters for Tienjin, Hubei and Shanxi in 1984 are also listed for reference (Statistical Bureau

Table 6. Paremeters of grain production in Beijing and several neighboring provinces (municipality)

	arable land (10^4 ha)	plantation area (10^4 ha)	total yield (10^4 t.)	per capita (kg)	per ha. (kg)
Beijing					
1980	42.5	60.5	180.5	200.1	3415
1984	42.2	52.3	212.5	223.3	4155
Tienjin		48.7	131.5	164.6	2700
Hubei		665.6	1870.0	340.8	2813
Shanxi		332.9	872.0	335.4	2618

1982, Hydrological Bureau 1987, and He Kung 1985).

If the yield per hactare in Table 6 is compared with the recent achievements of rainfed agriculture, it is clear that irrigation is not effective in grain production. This is because the grain yield of rainfed agriculture using advanced technology has reached 7 t./ha., or even 11 t/ha, in a large experimental region (Cheng Ipen 1991), which is much larger than the mean grain yield in any of the provinces or municipalities of North China, no matter how far irrigation is expanded. But this does not mean that irrigation should be cut in any circumstance. For industry and urban life, due to difficulties in its collection, groundwater scattered in fields and wells is unavailable. If this water remains unexploited in the ground, it cannot be recharged during the next rainy season. So if irrigation is limited in extent to its renewable part, ground water still may be beneficially used for irrigation. After its exploitation for urban life and industry the surplus runoff may be also available for agriculture.

There is a good possibility of overcoming water shortages if all kinds of water resources, especially W_2, in water deficient region are as rationally exploited as the model suggests. In other climate regions the water balance has other relationships, that require special analysis and investigation for effective strategies to deal with their respective water problems.

POPULATION AND CLIMATE IN RELATION WITH THE HUANGHE

The Huanghe river has played an important role in the strong population fluctuations in ancient China (Beijing Normal Institute *et al.*, 1982). Since the beginning of Chinese history, until the Song Dynasty (960–1279A.D.), the middle and lower reaches of Huanghe was the central region of China, and was inhabited by the overwhelming majority of the Chinese population. Its population fluctuations dominated the whole country's population fluctuations.

Demographic history confirms that Chinese population fluctuation was closely connected with the life cycles of the feudal dynasties (Fig. 5). West Han (206B.C.–8A.D.)

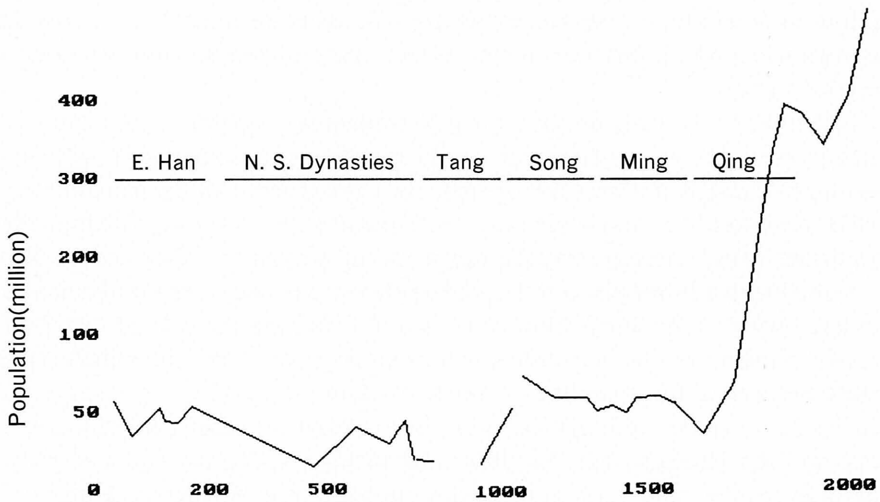

Fig. 5. Population fluctuation in China.

was one of the most prosperous periods in Chinese history with a population over 60 million. Subsequently population fluctuation was below this upper limit. In the most distressed periods, such as Wang Mang's period after West Han, the period of Southern and Northern Dynasties, and the period of Five Dynasties, the Chinese population fell to its lowest limit around 20 millions.

In population fluctuation, beside social and political disturbances, natural disasters were also very important factors. Generally, social and natural factors were inter-related and formed a self-amplifying system.

The Huanghe, as a river with a high silt content in its water flow, is a very powerful transporter of silt from the Loess Plateau, where intensive soil erosion orginates the huge silt volumes of the Huanghe River. When the flow arrives at the middle and lower reaches of the Huanghe, the densely populated North China Plain, the flow slows and is unable to carry so much silt downstream. As the surplus silt is deposited, the riverbed would be dominated by a process of continuous elevation, so long as soil erosion on the loess plateau had not be reduced due to cultivation.

Cultivation of farmland is the most important factor in soil erosion on the Loess Plateau. This plateau is the border region between Chinese agricultural and the northern nomadic peoples, with incessant fighting for control of the region. So soil erosion on loess plateau is determined by which people controls this region.

With the founding of a new dynasty China usually became strong enough to control this region and favourable conditions would be formed for cultivation expansion on Loess Plateau. As result of cultivation more and more silt was flow-transported to the middle and lower reaches of the Huanghe. As the riverbed quickly silted up in this area, the height of embankment had to be increased in order to prevent floods. The higher the riverbed and embankment became, the greater the danger of flooding would arise. However, in this prosperous dynastic period the government was strong enough to maintain the embankment. Water still could be controled, but the danger was evergrowing, which with the passing of time transformed flooding into a far more destructive force.

In the period of dynastic decline, the government was unable to maintain the embankment, even though the Huanghe was in very dangerous condition because of its highly elevated riverbed. Great floods frequently broke through the embankment and rushed down into plain, amplifying the flood disaster. In such a way Huanghe played an important role in accelerating the down-fall of a dynasty. After serious floods a new riverbed with a lower position might be formed. Furthermore silt alluviation also decreased, owing to the desertation of farmland following the invasion of the Loess Plateau by nomadic people from the north. Improvement of the Huanghe's condition probably occured at the founding of a new dynasty.

The linkage between population and the political situation through the Loess Plateau and the Huanghe may be illustrated in Fig. 6. The life cycle of a dynasty resonates in relation to the natural disasters caused by the Huanghe can be expressed in Fig. 7.

It is important to notice that the above mentioned process between political and natural factors in disaster formation still exists, though its influence is much reduced now.

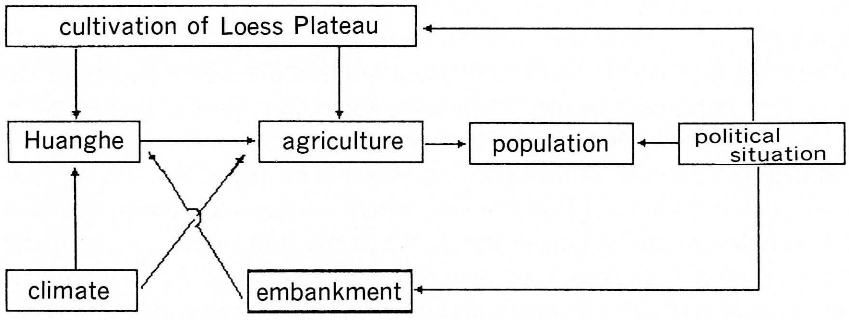

Fig. 6. The phases of natural disasters and the society in response.

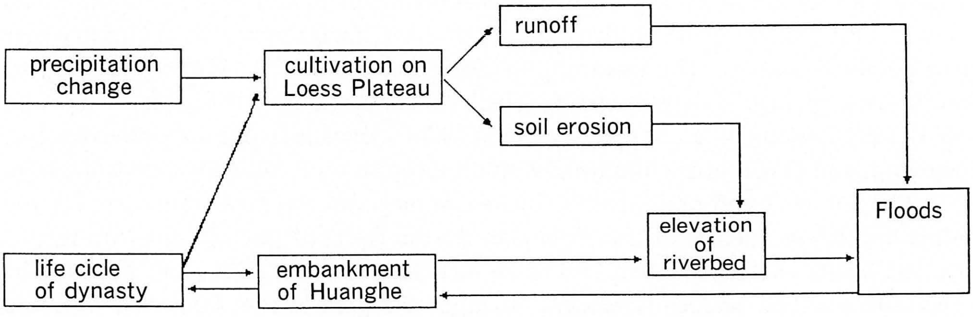

Fig. 7. Resonance between natural calamities and society.

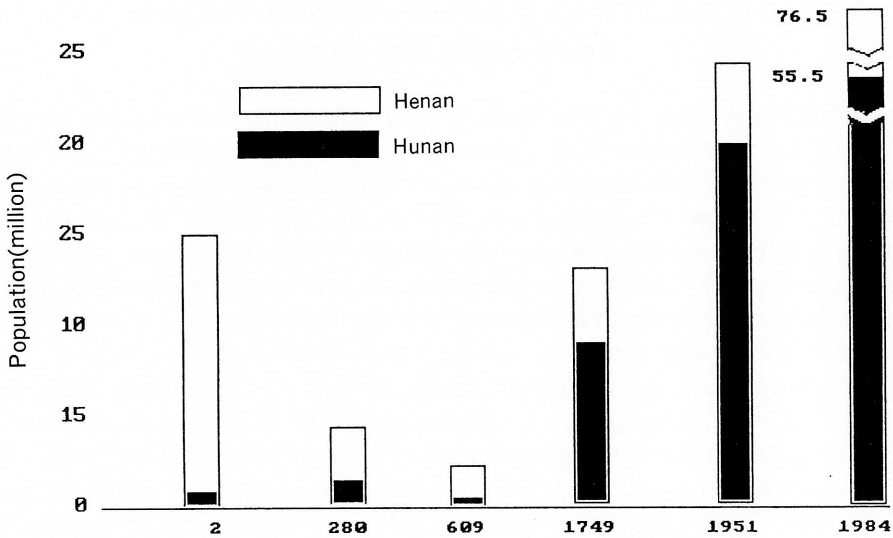

Fig. 8. Population of Henan (mid reach of Huanghe, area: 1.6×110^4 km^2) and Hunan (south of Yangtze, area: 2.0×10^4 km^2).

During the Song Dynasty the population distribution of China began to change, mainly due to the rapid increase of population in Yangtze River Valley and southern regions, a consequence of great population migration from north to south owing to the occupation of Huanghe Basin by Manchurians and other nomadic pepoles. The proportion of population in the middle and lower reaches of the Huanghe decreased step by step, although the population remained the densest in the country until now (Fig. 8). Since then the Chinese population has fluctuated around a much higher level and with a relatively smaller amplitude, owing to the smoothing effect of the larger population in other regions of China.

In the period of the Qing Dynasty (1644–1911), China entered a long stable and prosperous period during which the Chinese population increased from 30 to 400 million. Especially during the reign of emperor Qianlon (1736–1795) the Chinese population tripled due to social prosperity and the relatively low level of natural disasters.

Until now the Huanghe still played an important role in the amplification of natural disasters. The North China Plain, with the densest population in the country, is the most vulnerable region to climatic change in China. In this region not only are there frequent and severe droughts and floods, there are also disasters transported from Loess Plateau via the Huanghe. Consequently disaster mitigation engineering in the North China Plain should also involve water and soil conservation on Loess Plateau with the aim of reducing the silt content in the flow of Huanghe.

VULNERABILITY AND DEVELOPMENT IN ARID AND SEMI-ARID REGIONS

The northwestern half of China's territory is a vast area of arid and semi-arid climates. For over populated East China this region is of particular strategic importance in development. Thermal and radiational resources are very rich, but the shortage of precipitation seriously limits the exploitation of this region. So its development is entirely dependent on the solution of the water problem. There are lots of reasons to believe that the aridity there is quite doubtful, not only because there is considerable runoff from the surrounding mountainous regions, but also because of the very low efficiency in water usage compared with that in the eastern part of China.

Xinjiang is a representative region of the Northwest arid zone (Zhang 1990). It has an area of 1.65 million km^2 and precipitation of 243 billion tons, in which about 205 billion tons is in mountainous regions with an area of about 710,000 km^2 (44% of the total). In the basins there is only 38 billion tons of precipitation, but evaporation over its 970,000 km^2 land surface is much greater than precipitation. In the mountainous regions evaporation is only 118.4 billion tons. So there is about 86.4 billion tons of runoff and groundwater, which is the main water resource for maintaining the oasis agriculture at the foot of the mountains.

Tarim Basin, Qaidam Basin and Alxa region are referred to as extreme arid regions with annual precipitation below 100 mm while the evaporation capacity is over 1500 mm. Regular runoff from surrounding mountains is especially important for the development of socioeconomies there (Zhang 1990).

Quaidam Basin has an area of 120 thousand km^2 and normal annual precipitation is about 30 mm, but the water resource is about 7.2 billion tons, including 4.4 billion tons runoff from the surrounding mountains and 2.8 billion tons of ground water which mainly originates from the mountain region.

Tarim Basin is about 324 thousand km^2 in area with an annual precipitation below 50 mm, however, every year it obtains about 60 billion tons of runoff and ground water from the mountains.

Alxa region is 270 thousand km^2 in area with a mean yearly precipitation lower than 100 mm, but it receives about 1.4 billion tons of water resources from the mountains.

In the arid and semi-arid regions of China population density is extremely low and farmlands occupy only a small portion of the area. Thus the water resource per capita, or per unit of farmland is considerably higher than the country's mean value, as shown in Table 7.

Xinjiang has 4% of total precipitation but only 1% of the country's total population and economic output. That means the water efficiency in this region is only about a quarter of that in the rest of the country.

Furthermore, a comparison of Xinjiang with Shandong and Henan is made in Table 8. Clearly, the water resource in Xinjiang exceeds the total of that in Shandong and Henan, but the population, grain yield, cotton and edible oil of the later two provinces are respectively as much as 11.37, 11.97, 15.34, and 10.83 times greater than those in Xinjiang. This tremendous divergence of efficiency in water usage reflects the

Table 7. Socioeconomical parameters in extremely arid regions of China

	persons per km^2	water res. per capita	water res. per hectare of farmland
Qaidam	2^+	28800 t.	10000 t.
Tarim	2^-	100000 t.	20000 t.
Alxa	1^-	>6000 t.	
China		2700 t.	8730 t.

Table 8. Water and socioeconomical parameters (1984)

	precipitation (10^8 t.)	water res. (10^8 t.)	population (10^4 persons)	grain (10^8 kg)	cotton (10^5 kg)	edible oil (10^5 kg)
Shandong	1111	335.0	7637	304.4	17250	2164
Henan	1300	407.7	7646	290.4	12250	1820
Xinjiang	2429	882.8	1344	49.7	1923	525

relative levels of development in East and West of China, and the under exploitation of water resources in the arid and semi-arid regions than in the moist monsoon regions of China.

In North China experiments with ecological agriculture, sheltered agriculture and rainfed agriculture, as well as the court yard economy of peasant households, show a large potential for water usage even in semi-humid regions. These water saving approaches are more powerful in arid and semi-arid regions.

For example, in Gaoxigou Village, Mizhi County, Shaanxi Province, there were 200 hectares of farmland used for extensive cultivation in the 1950s. The grain yield was only about 40 tons per annum, and soil erosion was very serious. From 1959 there was an attempt to reduce the area of farmland in order to increase forestation and grasslands. By 1972, only 71 hectares of farmland remained, reclaimed as terrace fields, 70 hectares of land had been forested and 66 hectares of land had been grassed. The grain yield had steadily increased to 280 tons per annum, as much as 7 times greater than in the 1950s. Besides, forestry and animal husbandry income provided over 10% of the total.

Another example is the development of rainfed agriculture. In Central Shanxi Prefecture a cultivation technology called "Plantation in furrows with ridges covered by plastic film" was experimented with and it achieved tremendous success. In 1990 there were 1,365 hectares for experimentation which achieved a corn yield of 6.96 tons per hectare, about 63.7% more than in the non-experimental fields (Cheng Ipen 1991).

In the Weibei Highlands of Shaanxi Province a technology called "Promotion of water exploitation by fertilizers" turned 23 countries from grain deficient to grain surplus regions. Fertilizers induced winter wheat to lay roots deeper than 200 cm into the soil layer, where it is possible for the plants to take far more moisture and give a good harvest even in a dry climate.

In arid and semi-arid regions the variability of precipitation is extremely large. Sometimes the rainfall amount may be over several hundred millimeters in one or several days. In other words, the precipitation of one or two years may be concentrated into one or two days. This climatic pecularity requires that the water storage capacity should be large enough to keep the water of such intensive rain in the same spot.

Experience shows that it is possible with terraced fields, horizontal ditches and scale pits, associated with forestation and grassing, to completely take up 100 mm raifall in the same spot. Vegetation can grow in conditions of water accumulation in the artificial hollow topographical structures. Trees and intergrowing vegetation can prevent soil erosion and protect the terraced fields, ditches and pits.

It may be suggested that if in every 10 km^2 some small water reservoirs with total volume of about one million m^3 are built, then another 100 mm of rainfall can be held. If in every 10^5 km^2 (about the size of Zheijiang Province) some large water reservoirs with total volume of 10^{10} m^3 (about two Xinanjiang water reservoirs) are built, then a third 100 mm of rainfall may be held.

In summary, the total combined capacity of water reservoirs and ecological system plus the soil layers is sufficient to hold any torrential rain water of about 500 mm, which is very valuable for solving water problems in water deficient regions.

THE SOCIETY-CLIMATE RESONANCE

The quasiperiodicity of natural disasters has four major phases: brewage (B), explosion (E), spread (S) and disperson (D) (Zhang 1989).

Earthquake brewage is an accumulation process of tectonic stress or heat stress at the quake center. When the process is completed, the stress may be rapidly released causing a violent and unexpected earthquake. The disaster spreads wider and wider through fires, epidemic, etc. Afterwards the self-regulation effect in society and nature allows for gradual recovery to normality. Then, a new disaster is brewed.

Climatic calamities have a similar quasiperiodicity to earthquake calamities. The convergence of a warm moist air stream with a cold air stream is the climatic background to the brewing of torrential rain. The lattitudinal distribution of solar radiation, sea-land differences, the difference between underlying surfaces covered by or free from icecover etc., form the complicated distribution pattern of heat sources and sinks, which play the role of the macro-background in the formation and maintainence of the circulation of torrential rain in specific regions. The suddenness of torrential rain is explosive in character. This is the process which ruins houses and crops, and due to harvest failure cauces epidemics and famine. Afterwards, the disaster's impact gradually dies out through the relief effort of society and the recovery mechanism of Nature. Then the next disaster is brewed.

However, climatic disasters are quite different from earthquake disasters, because they may be either positive, or negative, such as floods and droughts, or heat and cold damage. Besides, climatic calamities are more frequent and wide spread. The overlapping of phases from one disaster to another is possible. It is also necessary to consider the possibility of opposite calamities when a disaster happens.

Corresponding to the quasiperiodical variation of natural disasters, the social activities of mankind also have four phases, namely: unawareness (U); panic (P); relief (F); and recovery (R). These phases deeply reflect the psychological and social activities in every field of human activity.

The explosive disasters such as earthquakes, torrential rain, landslides, etc., are especially prominent in the four phases. When it is brewing, a tranquil life prevails in a society which is generally unaware of impending disaster. Unawareness is a dangerous psychological state which disarms peoples responses prior to the sudden appearance of a disaster. Inevitably the society will fall into panic. Long after the disaster has passed the society will again become unaware of the next calamity.

The situation for extensive disasters, such as drought, is quite similar. A drought becomes worse only because it has a long duration. The suddenness in the psychological reflection of the people is ever growing, as the duration of a drought lingers on. On the contrary, sudden disasters, such as torrential rain, precipitously arrive and have almost no duration.

Natural disasters four phases and the relevant four phases of human response have a relational resonance which is shown in Fig. 9.

This resonance is also a process of self-amplification in which unawareness is a key link. Unawareness is the source of panic prior to disaster. Why people do not take the consequences of disasters seriously to heart despite the numerous historical examples? That is because everyday business discolors impressions of disaster, the impression of which is not so urgent in the brewing phase.

There is a great change in the situation as science and technology develop. Science not only reveals the physical processes in the formation and expansion of natural disasters, but also gives us the knowledge of how to mitigate their impact. That makes it possible to turn the unawarness phase into a phase of disaster forecasting and preparation, in order to mitigate the impact of impanding disaster. The four phases of psychological processes would be transformed into the following: scientific research and design; disaster forecasting; disaster mitigation; and the furthering of research and design.

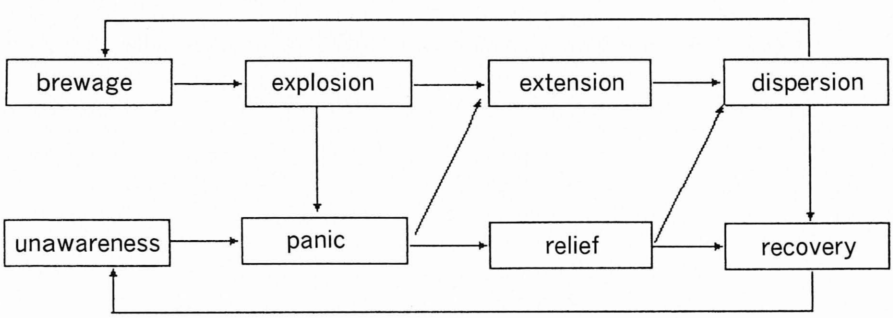

Fig. 9. The phases of natural disasters and the of the society.

Owing to the changed psychological processes the resonance between this process and the four phased processes of the natural disaster would be turned into a self-dampening disaster cycle in the Nature-Man System. When natural disasters lose its resonance on society damage would shrink and frequency of occurrence would be minimized. A period with little occurrence of disasters would come.

VULNERABILITY AND DEVELOPMENT IN HILLY AND MOUNTAINOUS REGIONS

In China hilly and mountainous regions are in general poorer than plain regions. As previously mentioned, poverty in hilly and mountainous regions originates from the unfavourable climatic conditons, but analysis of the climate resources shows that this view point is quite doubtful.

Tabel 9 gives a comparison of climatic conditions for some mountain stations in Guizhou Province, and several stations in the plains which are on the same latitude.

In mountainous regions the temperature is much milder than in the plains, despite this their annual means are approximately the same. Days with the temperature≥35°N and the low temperature harmful to sustaining the forest economy in mountainous regions, are considerably less than those in the plain.

Annual precipitation at the plain stations is greater owing to the differences in macroclimatic conditions, and the fact that the mountain stations are located in valleys where the precipitation is too small to be representative for the whole region. On the contrary the precipitation in the prime of growth season is much greater in the mountainous region.

For example, the precipitation between July and September for Nanchang is 306 mm, for Changsa 299 mm, but in Zhinshui it is 545 mm and in Sinan 355 mm, which is very favourable for agricultural production. Furthermore, the most favourable aspect of the mountainous climate is in the diversity of climatic types in a small region. Especially in the subtropical zone, any type of climate from a tropical temperate to a polar climate may coexist on the same mountain slope. However, in the plain the climate is far more monotonous. For example, there are three climate types in Sangzhi county, located in mountainous region of Hunan Province: as shown in

Table 9. Climate conditions of some stations (1951–1980) in 28°N–29°N zone

Station	altitude (m)	a. precip (mm)	a. temp. (°C)	days≥35°C	extr. low temp.
Changsa	44.9	1422.4	17.2	30.4	−9.5
Nanchang	46.7	1598.0	17.5	32.2	−7.7
New Delhi	220.0	715.0	25.3	—	—
Zhinshui	293.0	1322.1	18.1	25.0	−1.9
Sinan	416.3	1168.5	17.2	19.4	−5.5

Table 10. In such a small county a climatic difference of as much as 4°C and 400 mm may be observed. These differences are perfectly comparable with those of regions in the plain, which are separated by more than several hundred kilometers.

Most distinctive is the unusually diversified microclimate. For example, Chenjiahe Village, about 50 km from the county town of Sanzhi county, is an unusually warm region. After an intensive cold wave of 30 January, 1977, almost all the orange trees around the county town were frost damaged as the temperature fell to −10.2°C. However, in Chengjiahe, the lowest temperature was only −0.8°C., and the orange production for that year was particularly good.

Generally speaking, the subtropical zone (20–30°N) is famous for its arid climate. China has the largest moist subtropical mountainous region in the world. But until now this invaluable territorial resource is still underestimated and insufficiently exploited, despite of serious shortage of land resource in plain regions. In order to illustrate the abundant climate resource of China's subtropical hilly and mountainous regions, Fanjingshan mountain in Guizhou Province may be taken as an example (Wang 1982). The climate on different altitudes and slope directions is given in Tables 11 and 12.

It is interesting to note that the distribution of radiation, temperature and precipita-

Table 10. Climate regionalization of Sangzhi country

	altitude (m)	ann. temp. (°C)	ann. Precip. (mm)
Valleys	<500	16	1400
Hills	500–800	14–15	1700
Mountains	>800	12	1800

Table 11. Annual temperature of Fanjingshan

slope direction	luv side (Northwest)					summit
altitude (m)	370	800	1200	1600	2000	2400
temperature (°C)	16.2	14.1	12.2	10.1	8.1	6.0
	Lee side (southeast)					
altitude (m)	2000	1600	1200	800	456	
temerature (°C)	8.3	10.6	12.8	14.9	16.8	

Table 12. Annual precipitation of Fanjingshan

slope	luv side			Jindin	Lee side		
altitude (m)	370	850	1766	2244	1150	780	460
precipitation ratio (%)	0.63	1.23	1.33	1.00	0.52	0.47	0.48

tion with slope direction and altitude are prominently different from one another. That is the reason why the climate types formed by coordinating these climate elements are so diversified. One result of the climate diversity is that biological genotypes are very abundant. For example, in Fanjingshan region the woody plants have 406 species which belong to 70 families, 175 genera. Numerous invaluable medical herbs, rare birds and animals have been discovered in these mountains.

It is clear that the poverty of the vast hilly and mountainous regions in China cannot simply be explained as the result of unfavourable climate, it is also a result of insufficient knowledge and the misuse of climate resources. This is most striking in the domination of grain production in these regions, perfectly disregarding the great physicogeographical and climatic differences between the plain and moutainous regions. Monoculture is not able to exploit the diversity of climate resources in the hilly and mountainous regions, where pieces of land on slopes cannot keep soil fertile and repeatedly grow the same crop. Overcropping in uneven topographical regions inevitably intensifies soil erosion and destroys the ecological balance. In other words, degradation of the environment owing to land misuse is the mechanism that impoverishes the hilly and mountainous regions. The unique way out of poverty is through multicultivation. High economic output and ecological benefits are possible in these regions only on condition that every piece of land is used according to its own specific peculiarities, including climate.

In valleys and where it is suitable for constructing horizontal terraced fields conditions would be favourable for the development of plantation crops. Slopes are suitable for forestation and grassing. In the subtropical hilly and mountainous regions of China about 67 million hectares of grassland remain unexploited, despite its high productivity of forage grass which is at least about ten times greater than that in the premier grassland of Inner Mongolia.

In China's subtropical hilly and mountainous regions hydropower resources are extremely rich. Besides gigantic water reservoirs, micro power station may be constructed throughout the region, and supply sufficient energy for the exploitation of regions remote from the cities. A mountain water reservoir with its surrounding regions is generally multivalent.

A series of diversified cultivation models with tremendous economic success and good ecological side-effects, which have been proposed in recent years, show that China's hilly and mountainous regions can reach the same level of development as in the contiguous plains.

Besides, China's hilly and mountainous regions are rich in tourist resources. Multicolored scenic spots are located in diversified geomorphological conditions. Generally ancient China's architechtural style is skillfully associated with specific natural scenery, and with emotional poems and beautiful calligraphy sculptured on cliffs or on remaining temples has been admired by famous poets and painters throughout history. Such curiosities that combine natural beauty with the arts would be appreciated by tourists forever.

THE REGIONALIZATION OF VULNERABILITY IN CHINA

Vulnerability is decided by the socioeconomical load of climate resources and the production level, its scope and technology. The vulnerability would be higher, if the load is heavier in conditions that production remains on the same level. Generally for a certain level of insurance the load has to be smaller than the carrying capacity of the climate resources. Otherwise the socioeconomy would be highly vulnerable.

The coefficients of the socioeconomical load of water is the amount of socioeconomical quantities produced by consuming unit of water resource (W) or precipitation (R) (in 10^8 m^3). The representative quantities of socioeconomy are population (P), acreage under cultivation (a), grain yield (G), and total output of agriculture and industry (V). The coordination of the two sets of quantities can give eight kinds of load coeficients, namely: RP; WP; Ra; Wa; RG; WG; RV, and WV (Zhang 1992).

The charts of load coefficients (Figs. 10, and 11) are quite similar to one another, though there exist secondary differences, of interest only in detailed studies. But the coefficient charts have essential differences with the charts of precipitation or socioeconomy.

For example, the largest load is in the region of the North China Plain, but the largest precipitation and highest productivity are in the regions further to the south.

Considering these load coefficients with reference to climatological, socioeconomical and physical geographical charts, China can be divided into five regions and eleven subregions (Fig. 12), which can be described as follows:

Region A is characterized by the heaviest water socioeconomical load. There are two subregions:

A_1 includes Beijing, Tienjin, Hebei, Shandong and parts of Henan, Anhui, and part of Jiangsu north of the Huai River. The mean annual precipitation in this subregion is about 500–800 mm, but the runoff depth is only 90–170 mm. The water resources in this subregion is below 5% of the country's total, but the population and acreage under cultivation are both over 22% of the country's total. So this subregion has the heaviest load in China. Besides, this subregion is also distinguished by a high concentration of precipitation in summer, and a strong interannual variability of precipitation.

A_2 includes the main part of the Loess Plateau. The precipitation and runoff in this subregion are smaller than those in A_1. But the population density and economic output of A_2 are only about half of that in A_1. A_2 is the subregion with the second heaviest load in China. Intensive soil erosion in this subregion is the source of silt deposited in the riverbed in the middle and lower reaches of the Huanghe.

Region B is the northeastern part of China and the region with the second heaviest load in China. There are two subregions:

B_1 is the southern part of B including Liaonin and Jilin provinces. Precipitation here is near the average for China, but runoff is about 25–33% smaller than average. The population density is about 20% lower than the country's average, but economic output is rather high. So the socioeconomical load in this region is heavier than

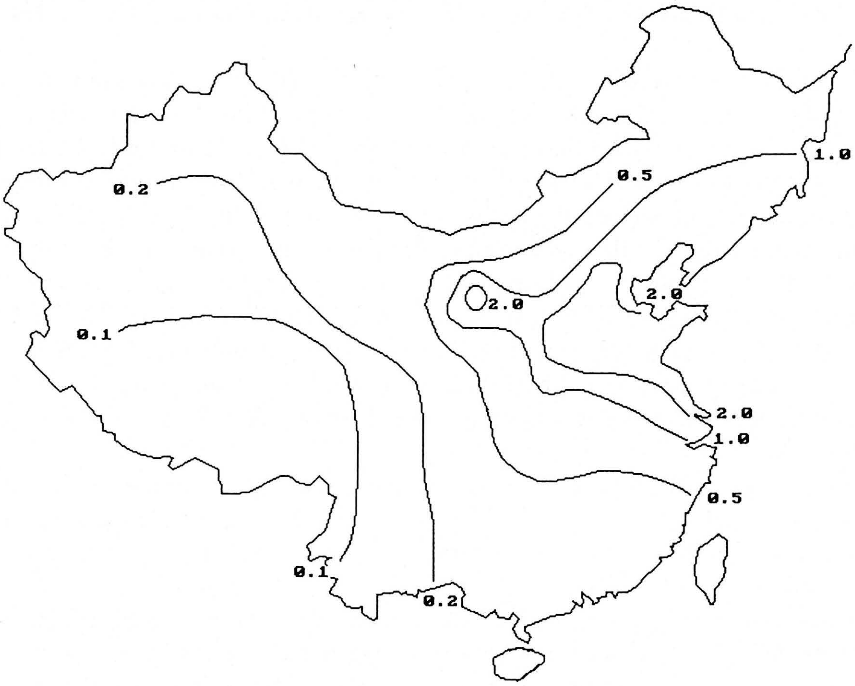

Fig. 10. Water grain load (kg/t) in China.

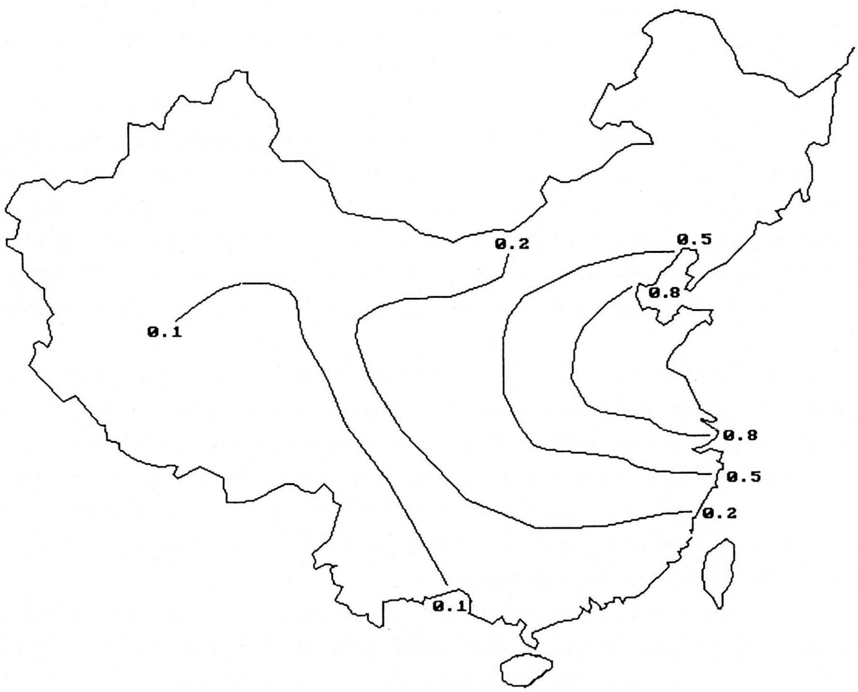

Fig. 11. Precipitation farmland load (ha/10^4 t) in China.

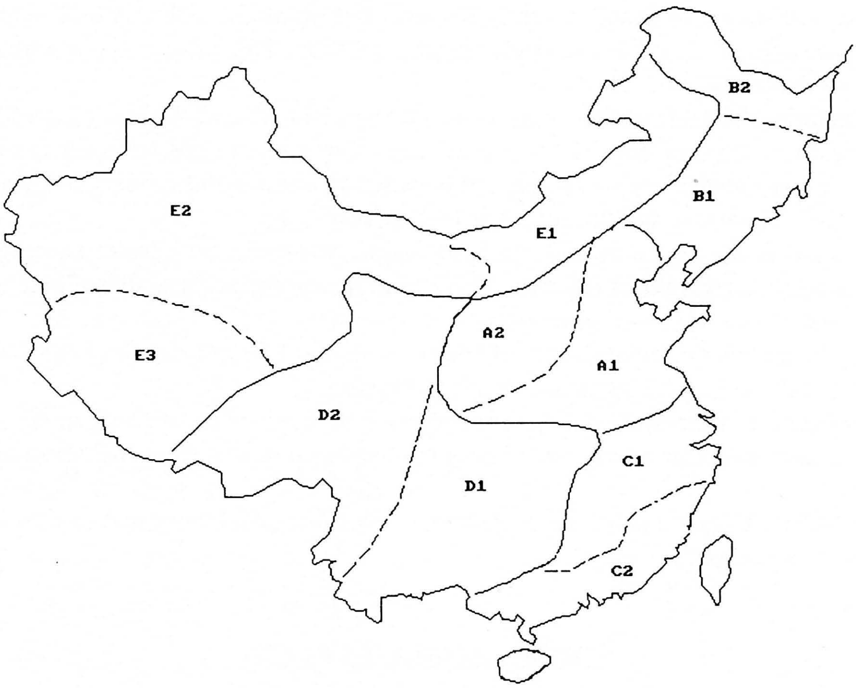

Fig. 12. Water socioeconomical regionalization of China.

average, and the economical load is heavier than the population load.

B_2 is Heilungjiang Province where the precipitation and water resources are smaller than those in B_1, but the socioeconomical load of water in B_2 is also lower than that in B_1, owing to the low density of population and comparatively low production output.

Region C includes the vast region south of the Huai River and east of 110°E. in the Yangtze River Basin, and east of 105°E. in the Pearl River Basin. There are two subregions.

C_1 is the middle and lower reaches of Yantze River Basin and the southern bank of the Huai River. The region's mean precipitation is about 1000–1500 mm, and runoff depth is about 400–800 mm. Both values are twice the country's average, but population density is the second largest after A_1. The region's economic output is very large. The water socioeconomical load nears the average for China.

C_2 includes south China and the south border zone of Zheijiang and Jiangxi Provinces. Precipitation in this subregion is the largest in China. But the population density and economical output are apparently smaller than those in C_1. Thus the water socioeconomical load is considerably low.

Region D is the southwest part of China where water is abundant, but the population density and economic output are small. This is a low load region. There are two subregions.

D_1 includes Sichuan, Guizhou and Yunnan Provinces. Regional mean precipitation is about 1200 mm and runoff depth is 570 mm. But population density and economic output are apparently lower than the average for China. This subregion has a small ecnomy to water load.

D_2 includes the Tibet plateau east of the 400 mm isohyet and the Hangduan Mountain region of Yunnan and Sichuan provinces. The regional precipitation is smaller than or nears the country's average, but population density and economic output are very small. The water socioeconomical load is very light.

Region E is the vast arid and semiarid region of Northwest China. The regional mean precipitation is about 100 mm. This region is very sparsely populated and poorly developed. There are three subregions.

E_1 is the middle and eastern part of Inner Mongolia. Precipitation is about 200–400 mm. China's main grasslands are in this subregion.

E_2 is the oasis agriculture region. Precipitation here is inadequate and cannot maintain any agriculture or animal husbandry if there is no runoff from the mountainous regions.

E_3 is the northwest part of Tibet Plateau. This subregion is very dry and cold, and almost uninhabited.

GREENHOUSE EFFECT

Global warming caused by an intensified greenhouse effect has become a focus of attention since the 1970s in scientific circles and in society, despite large amounts of research much remains unexplained. However, the prominently warmer climate of recent years seems to be further confirmation of this point. Supposing the greenhouse effect does exist, then in regard to its impact in East China the following can be suggested (Zhang 1989).

In China's monsoon regions the winter is more severe than in other regions on the same latitude owing to the dominance of cold winter monsoons from the polar regions. As indicated in the workshop held in Villach, Austria (28 Sept.–2 Oct. 1987), the greenhouse effect would induce a much stronger warming above the global average in polar regions north of 60°N. (Gordon 1988). A direct effect of the strong polar warming is a mitigation in the severity of the polar continental air mass, which inevitably reduces the strength of the cold winter monsoon in Eastern China. Consequently the weakening of the winter monsoon would be a factor in intensifying the warming of China's monsoon regions, in addition to the above average warming in the same latitude zone.

But there would be no desiccating in the midlatitudinal zone of China. Although water shortage has become an important problem in the development of inland and North China, there is abundant documentary and archaeological evidence to indicate that there has been moist periods in the past, and that high (low) temperature is usually accompanied by a moist (dry) climate in the time scale of 10^2–10^6 years. When the time scale is too large, there would apparently be a redistribution of continents and oceans, which could cover the temperature-precipitation relationship in conditions of fixed external forcing sources (Zhang 1989). The magnitude of temperature change would not be big enough to cause a precipitation response, so long as the time scale is under one hundred years. The time scale of the greenhouse effect is just inside the indicated range when the temperature-precipitation relationship is exposed.

As indicated by Zhu Kezhen (1972) the general trend of climate change in China is similar to that of the world. About 3000–7000 B.P. China was much warmer and moister than at present. Pieces of bone remains and grain unearthed in the ruins of Beipo primitive village near Xian (6000 B.P.), and at both of the capitals of the Sha Dynasty (4000 B.P.) and the In Dynasty (3000 B.P.), are of subtropical varieties which did not exist there in the last two thousand years. Besides, an oracle bone, in the time of emperor Wuding's reign (about 3300 B.P.), recorded that "an elephant was captured during a hunt" was unearthed in the ruin of the In capital, located north of Huanghe. This evidence convincingly indicates that before 3000 B.P., the middle and lower reaches of Huanghe was much warmer than at present.

It is interesting that this period was also very moist, in regard to which there are numerous legends about flooding in ancient China, such as "Sha Yu prevented floods by regulating watercourses" is a most famous example. There is also a lot of archaeological evidence that shows a warmer and moister climate than had previously existed, e.g. knives, and sickles made from large shells have been unearthed in the ruins of the Sha capital and other towns situated in middle reaches of Huanghe. Such large shells now can only be found in the Yangtze River, or to the south of the river. The ruins of Sha capital had been destroyed several times by floods, however, no floods ever arrive at the site of the ruin which is about 10 m higher than the riverbed.

In the period 301–588 A.D. the climate was very cold. Zhu Kezhen compared the phenological dates recorded in *Chi Min Yao Shu* (a famouse Chinese agricultural classic of the sixth century) with present ones, and discovered that in the sixth century phenological phenomena are about one month later, equavalent to a temperature about 2–3 °C colder than it is now (Zhu Kezhen 1972). This period also was very dry. Zhu Kezhen indicated that in the fourth century droughts rapidly increased, while in contrast floods rapidly decreased. In the period from 336 to 443 A.D. there were 41 droughts recorded, but no records of floods. Wang Chun (1992) comfirmed the results with a lot of new findings.

The another historic cold period was the mini ice age in the sixteenth and seventeenth centuries. This period was also very dry. From the dryness/wetness grade series the dry climate was very prominent (Zhang *et al.* 1983).

The linear relation between temperature and precipitation also has sufficient evidence in geological explorations. For example, M. Sarnthein (1978) published three charts respectively referring to the present, 18,000 years ago when the world was at its glacial maximum, and 6,000 years ago when the climate was at its warmest during the interglacial. It is very clear that in the coolest period (18000 B.P.) the world climate was far drier, but in the warmest period (6000 B.P.) the world climate was far moister.

The above proposed relationship between temperature and precipitation is mainifested in the annual variation of climate. It is generally recognized that precipitation is connected with the activities of frontal zones. But precipitation in the majority

Table 13. The temperature (°C) and saturated absolute humidity (g/m³) under standard atmospheric pressure

Temperature	0	10	16	20	24	28	30
abs. humidity	3.81	7.67	11.4	16.6	18.8	23.9	26.9

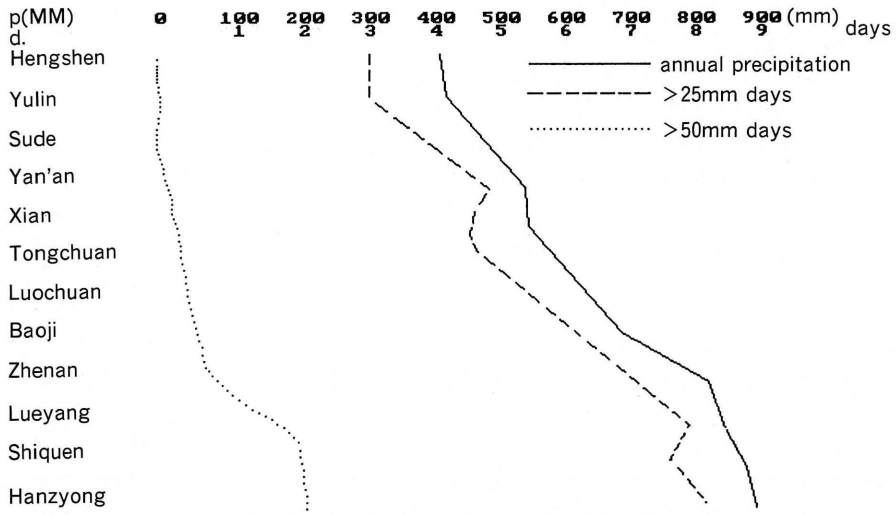

Fig. 13. Annual precipitation and days with large precipitation on the Loess Plateau.

of China's regions during the summer is far greater than in winter, although winter is the season with the strongest frontal zone activity. It is clear that moist instability plays a very important role in the formation of a dry and moist climate, unlike that of the rainy weather which is mainly connected with frontal activities in the temperate zone.

The growth of moist instability with temperature increase may be reflected in the close relationship between saturated absolute humidity and temperature (Table 13).

From Table 13 it can be seen that when air temperature is 10°C only 3.81 g of water can be released, if one cubic meter of air has ascended about 2 km some 10.3 g of water can be released when the temperature is 30°C, so long as other conditions remain the same. Released latent energy at 30°C is 3 times greater than that at 10°C.

It can be expected that precipitation increase will occur in North and inland China as the result of global warming, due to an intensified greenhouse effect. Because global warming would be an important factor in strengthening the summer monsoon which could push farther to north and inland. This is very favourable for the semi-arid border zone to be more frequently invaded by the warm moist air stream of the summer monsoon, which would cause greater precipitation. As a result, on the Loess Plateau which is located in border zone of summer monsoon, precipitation and soil erosion caused by torrential rains would be intensified (Figs 13, and 14). Simultaneous-

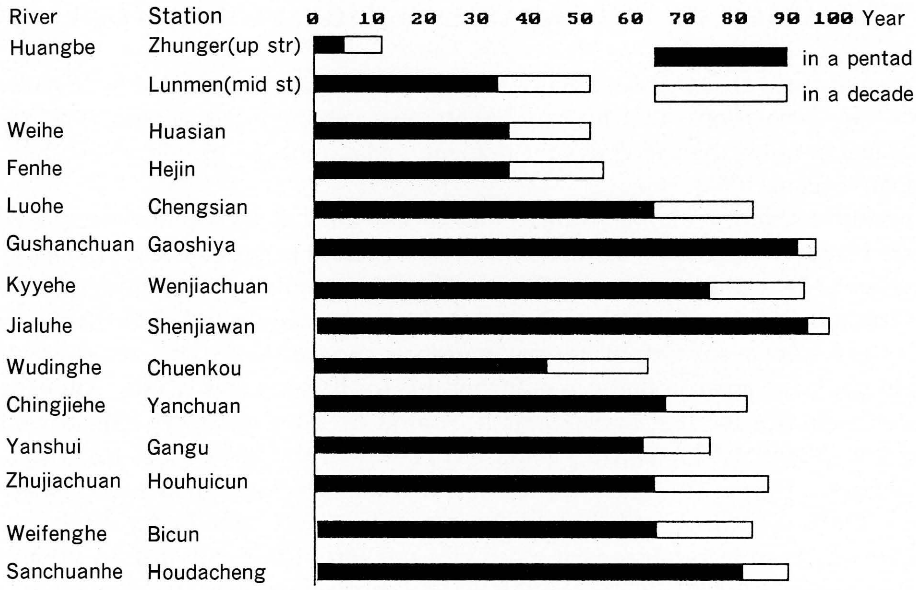

Fig. 14. The concentration of silt transportation in rivers on Loess Plateau.

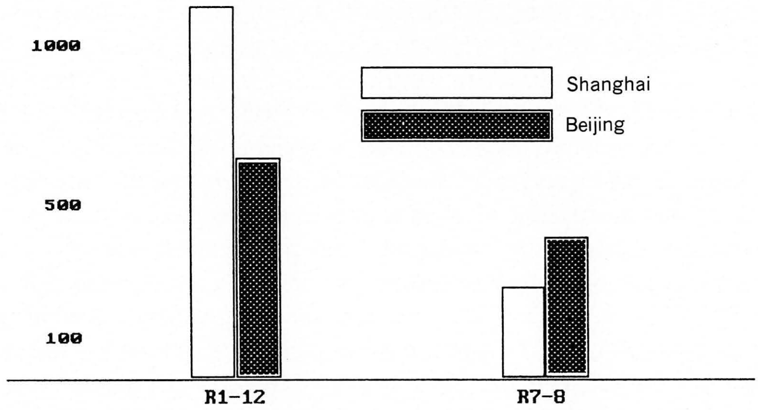

Fig. 15. A comparison of precipitation in Shanghai (31° 10' N, 12° 26' E) and Beijing (39° 48' N, 117° 28°' E).

ly the regions where the summer monsoon scarcely arrives would obtain the summer monsoon with its greater precipitation, as a result of global warming.

As the main rainbelt is located in the frontal region between the summer and winter monsoon, there is usually a summer drought region as the summer monsoon pushes further to north, and the subtropical high pressure comes to dominate the region. In the case where the summer monsoon becomes stronger following the rainbelt that moves further to the north, a summer drought could be observed in North China. Then the climate in North China while it would be more moist annually, but would be drier in summer (Fig. 15).

VARIATION OF VULNERABILITY THROUGH HISTORY

Human history consists of four major stages of development alternated by so-called "waves" or "revolutions." Each stage has its own specific fittest climate type and climate region suited to its level of development, and also has its specific vulnerability to climate (Zhang 1984).

In primitive society man was living similar to wild animals without any productive activity. Human vulnerability in that society was reflected as the resistant capacity of the human body to adverse climate. Favourable climate could have no prominent annual variation, and be sufficiently warm, so that human beings could obtain fruits, or flesh, from Nature at any time of the year in order to survive. At the same time humidity could not be so great so that it was favourable for bacteria and viruses. The most favourable climate for that society was a tropical or subtropical dry climate with sufficient water supply. The world's major birth places of ancient civilizations, such as Mesopotamia, Egypt, the Indus Valley and Yucatan are located in such climatic regions. Only the ancient Chinese civilization, in middle and lower reaches of Huanghe was born in a subtropical moist climate. But in this early-period summer drought was very prominent. Though this was a favourable climate, the variability of climate fequently induced dreadful calamities, due to the high vulnerability of human body to any climatic abnormality.

When climate changed from a warm age to a cold glacial age mankind could not avoid being confronted with an extraordinary environmental crisis (Zhang 1989). The main problem was how to survive in winter, because in this severe season the human body could not endure the unsual coldness, and no food could be found in Nature. Only the wisest primitive inhabitants had success in overcoming these difficulties by collecting plant seeds or raising captured animals in the warm seasons for the necessary winter food, as well as utilizing caves as primitive housing and tree leaves, or animal skins, as primitive clothing for insulation from the cold. However, this crisis promoted the first revolution in human history and initiated the development of human civilization. Primitive agriculture and animal husbandry, primitive clothing and housing, and even the beginning of using fire were splendid achievements for mankind in fighting the unfavourable climate. Since then Man entered the agricultural society.

In agricultural society Man began to be engaged in production and to have his productive force. This greatly improved his material life, because the food, clothing and other necessary living materials could be ensured by his own labour. The vulnerability of mankind to adverse climate was reduced from the body's resistant capacity to the conditions of agricultural production. Winter cold would no longer be a problem for mankind, however, the sufficient length of the growing season and timely precipitation now became the vitally important limitation.

In that society the level of production was rather low. Besides ensuring the necessary requirements for the producers and his family, labourers really had little surplus products for exchange. Labourers also could only cultivate nearby pieces of land, so the society was scattered in small villages with little intercourse. The society was in a semi-isolated state. At that time experience of the local climate for production and living was sufficient. From the viewpoint of agricultural climatology, agriculture could be developed only in conditions were the growing season is long enough to satisfy at least a single cropping, and also precipitation is sufficient for plantation. The vast plains in the temperate zone can satisfy these requirements and so became the most important regions of development for mankind in the Middle Ages.

In industrial society productivity achieved a high level through the introduction of machines into the production process. Manufacturers produced great amounts of the same products, not for themselves, but for exchange with others. This promoted the transformation of society from an isolated to an open one, in which transportation plays a key role. The vulnerability of society extended by transportation to climate, especially sea freight which is a high vulnerable branch of the national economy to climate, making it easy to spread the impacts of climate change through its linkage with other branches of socioeconomy. Climatic impact on transportation had a key role in industrial society. The most favourable region in this society is the region that is not only rich in natural resources, but also convenient for transportation with the outer world.

The development of socioeconomy is an accelerated process separating Man from Nature through the adoption of more powerful production technology, in order to deal with climatic calamities. Transportation links the suppliers and consumers and is also powerful tool in relief efforts. This is favourable in reducing the vulnerability of socioeconomy to climate.

At this stage science and technology play a key role. Scientific disciplines were formed in answer to different but urgent requirements of socioeconomical development. For climatology the local experiences of climate could no longer satisfy the requirements of the global market. Climatology, as a discipline of science, based on the worldwide meteorological observations is a necessity.

However, industrial society cannot engage in unlimited development on this limited earth surface. The contradiction between ever growing production and limited natural resources and environmental constraints is incessantly intensified, and turns inevitably to crisis. Such a crisis would be a destructive factor for both socioeconomical development and the earth's environment, so long as there is no way out from this serious situation.

VULNERABILITY IN INFORMATIONAL SOCIETY

Now the world is in its third wave which has brought about the imformational society. This society inherits tremendously powerful productive forces and also the serious problems of the industrial society. Naturally its main tasks are production development in the context of solving existing problems. The main problems are reflected as a series of crises, such as in the environment, energy, water, etc. In a word, these crises originate from a contradiction between the limited resources of the Earth's surface and the rapid growth of production, while at the same time neglecting the complicated relationship with the Earth's ecosystem.

Production is an extra process imposed on Nature in a quite recent geological timescale, which has become incompatible with the ecological balance on Earth. This incompatibility was not big enough to induce any significant influence on the natural environment before industrial society, owing to the low productivity of mankind. But the situation has been changed radically now that productive force is becoming so powerful, not only in creating a comfortable life for mankind, but also in inducing a series of environmental crisis, characterized mainly by the following two problems. The first problem is the expansion of farmland and construction at the cost of natural vegetation, in order to satisfy the ever growing population with sufficient agricultural products, residences and public utilities. As a result a series of environment degradations take place, such as soil erosion, desertification, etc., which are inevitable when the Earth surface is over exploited and loses the protection of natural vegetation. Another vitally important problem is the air pollution of anthropological sources. As mentioned above, the intensification of the greenhouse effect, owing to the growing concentration of carbon dioxide and other greenhouse gases, has become a central issue at present. Besides, the depletion of the ozone layer and acid rain are equally adverse to the ecosystem and human life.

Man should seek a way out of the present environmental crisis. There is a old Chinese saying: "those who tied the bell can untie it too." The crisis of the Nature-Man relationship that is formed in the process of socioeconomical development could also be solved by this process. History relates an example similar to this. The first environmental crisis originated with the approach of the quaternary ice age, which delivered a destructive attack on the normal life of primitive people, but it also opened up the era of civilization for mankind. Crisis cannot be considered as purely evil, it also stimulates people with a strong desire to seek new ways out of the crisis. Simultaneously it gives a golden key to open a new stage of development for mankind. The first environmental crisis was just such an event (Zhang 1989).

Similarly the present crisis in the Nature-Man relationship is also opening a new road to its settlement. That is the system theory. This is new scientific thinking aiming to treat multiple phenomenon as a unified system, with a reasonable structure capable of optimizing the whole.

For example, the optimum population may be scientifically projected by considering the resources and carrying capacity of the Earth's environment. The diffferent branches of national economy should be in resonable proportion to the scope of society. Natural resources could be exploited by recycling. There would be no waste, because the waste of one branch would be the resource of another. The natural ecosystem in the biosphere is a good example of such a system. The ecosystem not only ensures the sustainable prosperity and development of all varieties within this system, it also forms a mutually beneficial interrelationship with the environment. After this model a man made productive system can also be established.

Until now the greatest achievement of mankind is the setting up of individual branches of the socioeconomy. But these branches have not been optimally assembled into a system. Among them innumerable conflicts are inevitable. In such a situation assemblage of all the socioeconomical branches, as well as Nature and Man, into a unified system would be the first fundamental task for mankind in an informational society.

The Nature-Man System consists of three interconnected and undivided subsystems, namely: Nature, its resource supply and environmental carrying capacity; the science and technology available in production or the know-how for processing raw materials; and the material and spiritual requirements of mankind. These three sets of variables make the system extremely complicated. It would be very difficult to delineate even the abnormalities of the system, never mind its optimization. The precondition for handling this system is to collect all the information about every major part of these systems and their changes for establishing its optimization.

It is very important in informational socity to fully utilize information for adjusting the structure of the national economy, in order to keep it in balance and in harmony with the Nature. For this purpose a series of soft sciences are necessary. Soft sciences explain the principles and methodology of management and planning for the optimum manipulation of productive forces. They play the guiding role in development. Advanced technology is the result of the development of hard sciences, which cannot develop any further without the help of soft sciences, because every branch of technology and production has become so closely interrelated with each other. If any

Table 14. Socioeconomical states and their relations with Nature in different stages of development

Wave	1st	2nd	3rd	
Society	primitive	agricultural	industrial	imformational
production type	none	manual	machinery	automatization
Key demands	food	food, clothing housing	tools, equipment	social need plus environmental need
sensible fields to climate	human body	growth season of crops	transportation	balance of NMS
favourable climate	warm dry climate with water supply	temperate zone	temperate zone	whole globe
climate calamities	physical impacts on human body	harvest failure	traffic accidents	deterioration of harmony in NMS
structure of society	scattered groups	semiclosed villages	open to market	organic whole
leading form of knowledge	instinct for seeking food	local experience	descipline of hard science	soft science
NMS	Nature governs Man	Man began to separate from Nature	conflicts between Nature and Man	Man governs Nature

one of them advances too rapidly, or stagnates, the other branches are influenced directly or indirectly. Only by the employment of soft sciences can the balance among them be restored and improved.

The vulnerability of the socioeconomy to climatic change in the informational society cannot be divided from injury to the balance in Nature-Man System. In the informational society any injury to the balance of the social system, natural system or Nature-Man System would be more serious than natural calamities.

In informational society human activities are not only affected by climatic change, but also actively affect climatic change. Here the causes and results are closely interwoven. So an assessment of climatic impact is no longer a periphirical scientific problem between two related disciplines, but a problem that converges on many concerned disciplines. Therefore approaches in dealing with climatic impact should look at the readjustment of the whole Nature-Man System. That is possible only through the study and planning of socioeconomical development with consideration of all the influential factors, in which climate change plays an outstanding role because of its high variability.

In summary, in informational society Man and Nature have been associated into an unified organic system. Man can manipulate and optimize this system. And through this system the vulnerability of socioeconomy to climate could be reduced to its lowest limit, and natural resources may be used to their maximum potential. Any region on the Earth surface would be available for the development of mankind. So the exploitation and maniputation of the whole globe is now on the agenda.

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