Landuse Pattern and Global Warming Effects in China

UCHIJIMA Zenbei
(Former President of Miyazaki Municipal University)

1. Introduction

Natural environment in China is now drastically changing, causing severe pollutions of air, water, and soil. These are mainly becasue of supprisingly rapid proceeding of industrialization and urbanization in that country. On the other hand, global climatic warming due to massive use of fossil fuels is bringing about the changes in climatic resources in China as well as world. In this report, changes of landuse pattern in China are first studied to make clear the change in the per capita areas of forest and arable lands with population density. Effects of global climatic warming are second investigated to assess effects of projected climatic warming upon agroclimatic resources in China.

2. Change in landuse pattern with population density

The data sets of the landuse and population of China and Japan provided by the National Census of the both countries were analyzed to find out the dependence of per capita areas of forest and arable lands upon population density. Figure 1 shows evidently that the per capita area of forest decreases rapidly with increasing the population density. The relation between the per capita forest area (a_f, ha/capita) and the population density(p, capita/km^2) was approximated by

$$a_f = 85.5\,p^{-1.32} \qquad \text{China}$$
$$a_f = 125.5\,p^{-1.15} \qquad \text{Japan}$$

The above relations indicate that the decrease in a_f with p is somewhat more rapid in China than in Japan.

Since the total land area of a study region is constant independently of time, with the increase in population density, forest lands and/or natural grass lands are converted first into arable lands, then as development proceeds, a portion of the arable lands begins to be used for residential districts and other purposes. Therefore, it is reasonable to expect that the decrease in the per capita area of arable lands with population starts at a population density higher than that at which the decrease in forest lands initiates evidently.

Figure 2 depicts the dependence of per capita area of arable lands on the population density in China and Japan. Although there is relatively large scatter of points, particularly in China, Figure 2 indicates that the conversion of arable lands into residential and/or factory districts becomes more considerable in a densely populated region than in a sparsely populated region. In Japan, the following relations were obtained.

$$a_a = l\,p^{-2/3} \qquad p < 10^2 \quad \text{capita/km}^2$$
$$a_a = m\,p^{-1.0} \qquad 10^2 \leqq p \leqq 10^3 \quad \text{capita/km}^2$$
$$a_a = n\,p^{-3/2} \qquad 10^3 \leqq p \quad \text{capita/km}^2$$

where l,m,and n denote numerical constants, respectively, a_a is the per capita arable land area(ha/capita).

2. Effects of global warming on agroclimatic resources in China

Recent assessments(IPCC,2001) suggest that increases in global mean temperatures in the range of 1.5-5.0 ℃ are likely to will probably occur between 2050 and 2100. These temperature changes will be sufficient to bring about long-term changes in agricultural and vegetation zones in China. The transitional climate scenario provided by the MRI-CGCM of Japan was used to assess the changes in agroclimatic resources in China. In addition, the climate senarios provided by the GCMs of GISS,GFDL,and UKMO for doubled concentration of atmospheric CO_2 were used to study effects of global warming on the potential evaporation in China.

The following two equations were, respectively, used to calculate two agro-climatic indexes-effective accumulated temperature (ΣT_{10},℃ days) and warmth index(WI, ℃ months).

$$\Sigma T_{10} = \Sigma\ T_{d,i} \qquad \text{for } T_d \geqq 10℃$$

$$WI = \Sigma\ (T_{m,j} - 5) \qquad \text{for } T_m \geqq 5℃$$

where $T_{d,i}$ and $T_{m,j}$ are daily mean temperature on day i, and monthly mean temperature in month j, respectively, k and m are, respectively, the number of days on which daily mean was equal to or above 10 ℃,and the number of months in which monthly mean was equal to or above 5 ℃. The following heat balance method was used to study effects of global warming to potential evaporation(mm/year).

$$E_0 = R_n / (1 + \beta)$$

where R_n and β are, respectively, net radiation and Bowen ratio calculated for fully wetted surfaces.

Figures 3 and 4 show the shift of ΣT_{10} and WI due to the projected global warming, respectively. As shown in Figs. 3 and 4, ΣT_{10} and WI shifted upwards in nearly parallel with the magnitude of climatic warming. The following empirical relaltions were obtained between the agroclimatic indexes under normal and warmed climatic conditions.

$$\Sigma T_{10,W} = 43.3 + 1.016\ \Sigma T_{10,N}$$
$$WI_W = 9.0 + 1.035\ WI_N \qquad \text{in 2050}$$
$$\Sigma T_{10,W} = 84.0 + 1.017\ \Sigma T_{10,N}$$
$$WI_W = 23.0 + 1.015\ WI_N \qquad \text{in 2100}$$

where suffixes N and W denote the agroclimatic indexes under normal and warmed climatic conditions,respectively.

Over the monsoon plain district of China east of about 105 - 110 ° E, it was found that the two agroclimatic indexes decrease exponentially with increasing the latitude. These exponential relationships were used to assess the northward shift of vegetation and agroclimatic zones with global warming. Under warmed climatic conditions corresponding to the climates in 2050 and 2100, $\Sigma T_{10,W}$ -values are about 450 and 850 ℃ days above the normal in northern district (the northernmost region of Tohoku district of China), about 500 and 930 ℃ days above in middle and lower districts of the Yangtze River, and about 550 and 950 ℃ days above in southern districts(south coastal region of China), respectively.

Since global warming accelerates water vapor diffusion earth's surfaces to the air due to increase in surface temperatures, potential evaporation is expected to increase with global warming. The following relations were obtained between potential evaporations($E_{0,N}$, mm/year) calculated for the normal climate and potential evaporations ($E_{0,W}$, mm/year) calculated for the warmed climates provided by the GCMs for doubled CO_2 concentration.

$E_{0,W} = 1.15\ E_{0,N}$ GISS-GCM

$E_{0,W} = 1.22\ E_{0,N}$ GFDL-GCM

$E_{0,W} = 1.31\ E_{0,N}$ UKMO-GCM

The above relations agreed well with other simulaltion results that evaporation could increase at a rate of 3-6% per climate warming of 1℃. Global mean of precipitation is expected to be an increase of about 10 % by 2100 due to global warming. On the other hand, it is pointed that inefficient rainfalls such as intensive and heavy rains will increase with the proceeding of global warming. Therefore, increases in an inefficient portion of rainfalls and the increases in potential evaporation with global warming should lead to the decrease in soil moisture ,particularly effective soil-water storage. The hydrological situation mentioned above implies that crop production and natural vegetation in inland districts of China should be suffered from frequent and severe dry weathers in the future.

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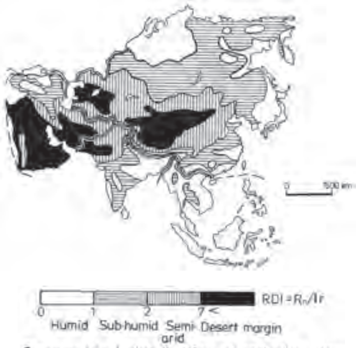
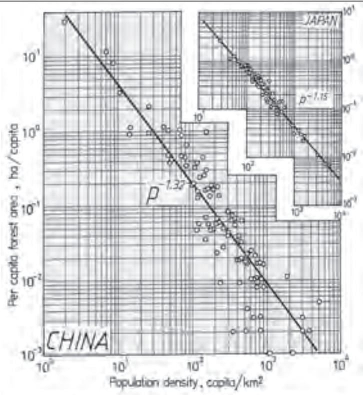
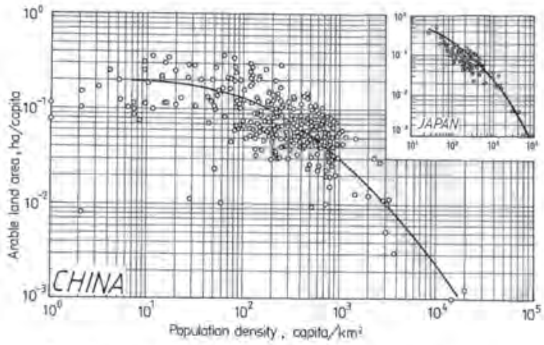
UCHIJIMA Zenbei
(Emeritus Professor of
OCHANOMIZU University)



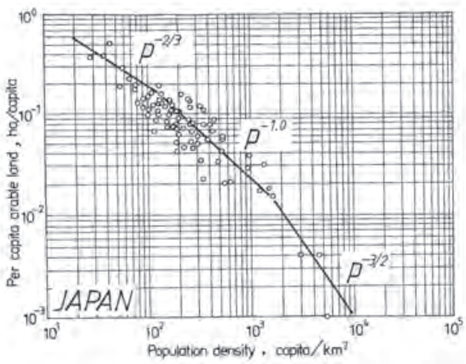
Geographical distribution of radiative dry index(RDI) in Asia



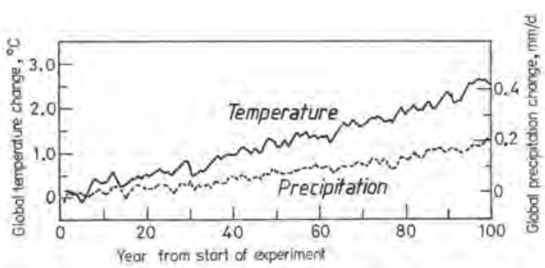
Dependence of forest area on population density



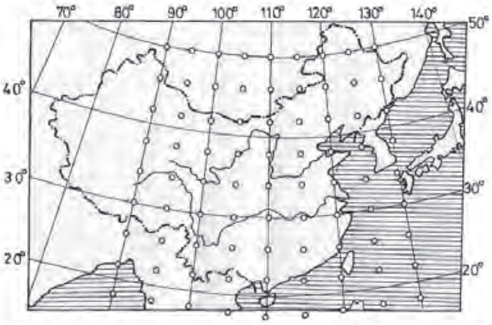
Dependence of arable land area on population density



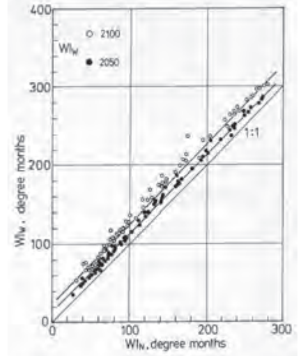
Dependence of arable land area on population density



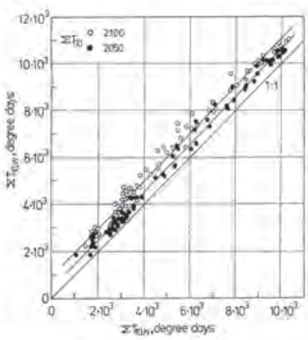
Global annual mean warming and precipitation simulated by MRI-CGCM using CO_2-1%/y increase



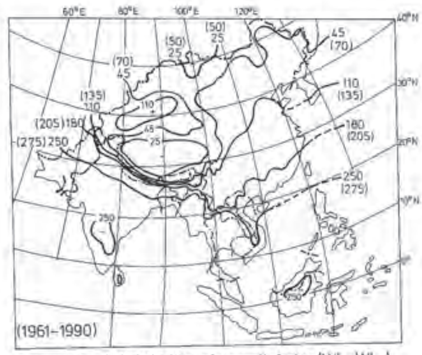
Geographical distribution of grid points for simulating CO_2 induced climate change by MRI CGCM



Changes in warmth index(WI) with global warming projected by MRI-CGCM

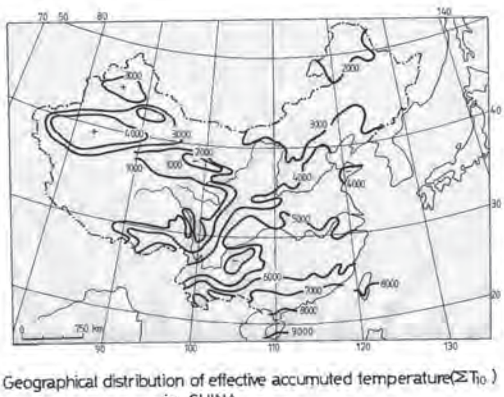


Changes in effective accumurated temperature(ΣT_{10}) with global warming projected by MRI-CGCM

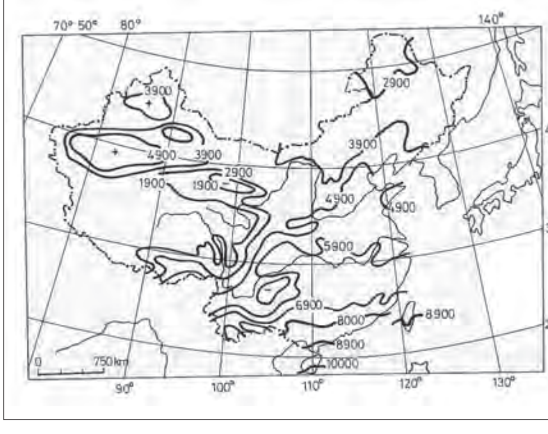


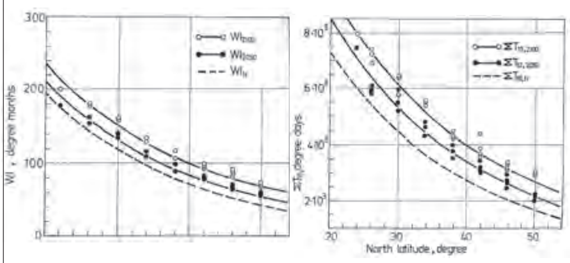
Geographical distribution of warmth index (WI_n, WI_w) in major part of temperate and tropical Asia

Figure in parenthesis indicates WI under warmed climate

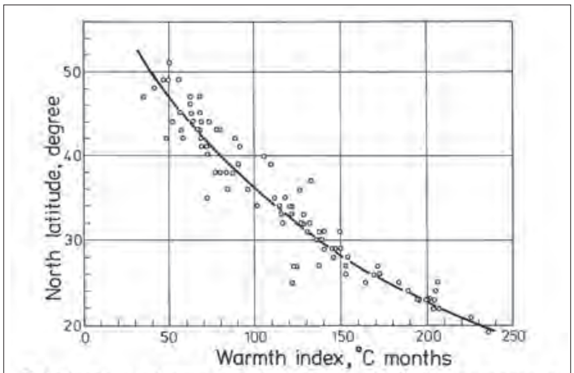


Geographical distribution of effective accumuted temperature(ΣT_{10}) in CHINA

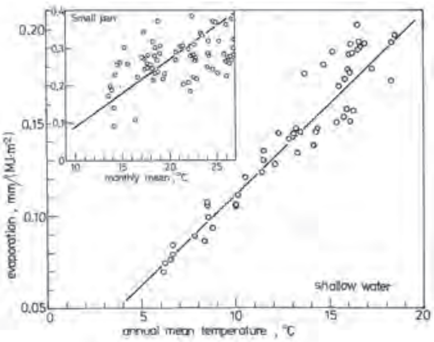




Estimated change in latitudinal distribution of WI and ΣT_{10} in the eastern monsoon region of CHINA due to global warming



Relationship between warmth index and latitude in monsoon region of east China



Evaporation rate per global solar radiation as a function of air temperature.