SECTION 4

The Effects on Altitudinal Shift of Rice Yield and Cultivable Area in Northern Japan

4.1. Introduction

The Hokkaido and Tohoku districts in northern Japan (cf. *Figure 1.1*) are major rice producing areas, accounting for about one-third of total Japanese rice production. However, these districts exhibit large interannual fluctuations of rice yield, because they are situated near the northern limit of production. The coefficient of variation of the yield index (representing annual yields) is higher here than elsewhere, amounting to 30.7% in Hokkaido and 13.9% in Tohoku (Uchijima, 1981; *see also* Subsection 3.3 above).

Rice growth is particularly sensitive to temperature conditions during the heading phase in the summer season, and cool weather damage due to low temperature is a recurrent phenomenon in the Hokkaido and Tohoku districts. The frequency of occurrence is about one year in six in northern Tohoku, and about one year in three or four in Hokkaido, the most northerly island in Japan (Uchijima, 1983). In this section we explore the effect of variations of summer temperature on rice yields and the cultivable area for rice in northern Japan.

4.2. Critical Temperatures in Rice Production

The usual cropping season for rice in Japan is from May to October. In order to complete the normal growth cycle, effective accumulated temperatures (ΣT_{10}) of at least 3200 degree-days in Tohoku and at least 2600 degree-days in Hokkaido (where early-ripening rice varieties are widespread) are required (Uchijima, 1983). Note that the estimate for Hokkaido is a refinement of that presented in Section 1 (*see Figure 1.6*).

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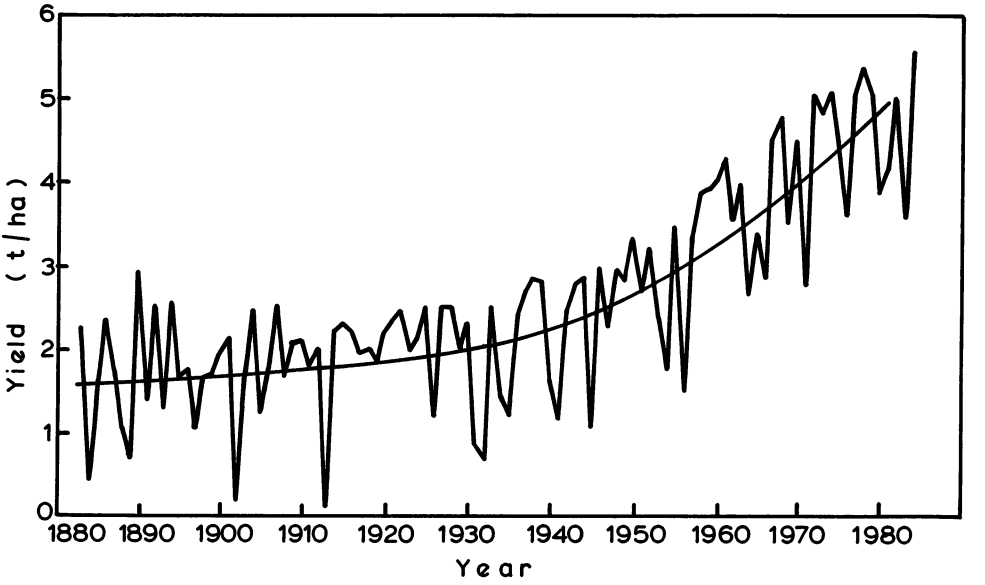

Figure 4.1. Variations in annual rice yield (tonnes/hectare) in Hokkaido, 1888–1983. Curved line indicates polynomial trend fitted to annual yields.

Rice cultivation in Tohoku and Hokkaido is commonly restricted to those areas with suitable average ΣT_{10} values. However, rice yields in any one year are closely related to the temperature in mid-summer, which includes the heading period. *Figure 4.1* shows the secular change of rice yield in Hokkaido over the period 1888–1983. The effect of cool summer damage is reflected in significantly reduced yields in some years. Since about 1950 average yield has increased considerably due to the development of agricultural technology.

The fluctuation of yield is closely related to yearly variations in temperature. To separate the effects of the development of agricultural technology and fluctuating weather upon rice yield, a yield index was calculated as:

$$IY = Y(t) / Y_T(t) \tag{4.1}$$

where IY is the yield index, and $Y(t)$ and $Y_T(t)$ denote, respectively, the actual rice yield and the trend rice yield in year t. The latter values were constructed by polynomial fit, as shown by the continuous smooth line in *Figure 4.1*. The yield index is closely related to the mean temperature for the July–August period in both Hokkaido and Tohoku (NIAS, 1975). These relationships (shown in *Figure 4.2*) can be well approximated by equations (4.2) and (4.3):

$$\text{Hokkaido:} \quad IY = 1.2035 - 0.04803\,(T_{7.8} - 22.5)^2 \tag{4.2}$$

$$\text{Tohoku:} \quad IY = 1.1207 - 0.03147\,(T_{7.8} - 24.5)^2 \tag{4.3}$$