Distribution of Damage Rates of Rates of Rice caused by Low Summer Temperature in Northern Japan

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Distribution of Damage Rates of Rice caused by Low Summer Temperature in Northeastern Japan

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We often hear a question "Does a cool summer do damage to rice any longer in Northeastern Japan?". Surely, severe damage caused by the low summer temperature has not been inflicted on rice in Northeastern Japan (Tohoku and Hokkaido)[1] since its last outbreak in Hokkaido in 1956. Particularly in the summer of that year, in spite of the fairly low temperature in Hokkaido and Tohoku, severe damage occurred only in Hokkaido. The fact convinced the author that the spread of the various new cultivation techniques has recently contributed the most to cut the damage caused by the low summer temperature, at least in Tohoku. However, the reactions in the rice agricultural regions to the low summer temperature have been varied regionally as well as chronologically. The author reported in his preliminary paper,[2] on the variations from the view point of the critical temperature.

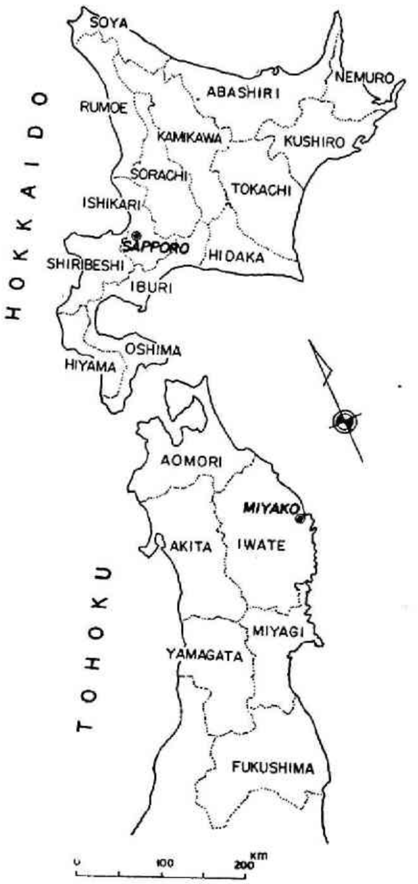
The purpose of such a study is to clarify the stability of the rice agriculture in Northeastern Japan, through the regional analysis of the cool-summer damages. Many papers on the cool-summer damage have been published, but there are very few studies, at least not so many on the distribution pattern of the damages or on the resistance to low summer temperature.[3]. The author tries to analyse the rice agricultural region from these two view points in the present study.

He will at first consider the influence of the cool-summer damage on the difference-curve between the average unit-yield of Japan and that of every prefecture in Northeastern Japan, and to classify into some types the distribution

1) See the index map. Northeastern Japan contains the Tohoku and Hokkaido districts. The Tohoku district consists of the six prefectures, Aomori, Iwate, Miyagi, Fukushima, Akita and Yamagata. And the Hokkaido district, being a prefecture itself in the statistical data, consists of the fourteen subdivisions, Ishikari, Sorachi, Kamikawa, Shiribeshi, Hiyama, Oshima, Iburi, Hidaka, Tokachi, Kushiro, Nemuro, Abashiri, Soya and Rumoe. But in the paper, we will consider the eleven subdivisions, excluding Kushiro, Nemuro and Soya, because the acreages of rice-fields in these subdivision are negligible.

2) H. Fukui (1958): Areal Difference and its Yearly Change of Cold Disaster on the Rice Cultivation of Northeast Japan, Sci. Rep. of Tohoku Univ., Seventh Series (Geography), No. 7. 29–38.

3) For example, see "Study on the literatures of cool-summer damage of rice, edited by Association of Japanese Agricultural Meteorology, 1955".



Index map of Northeastern Japan.

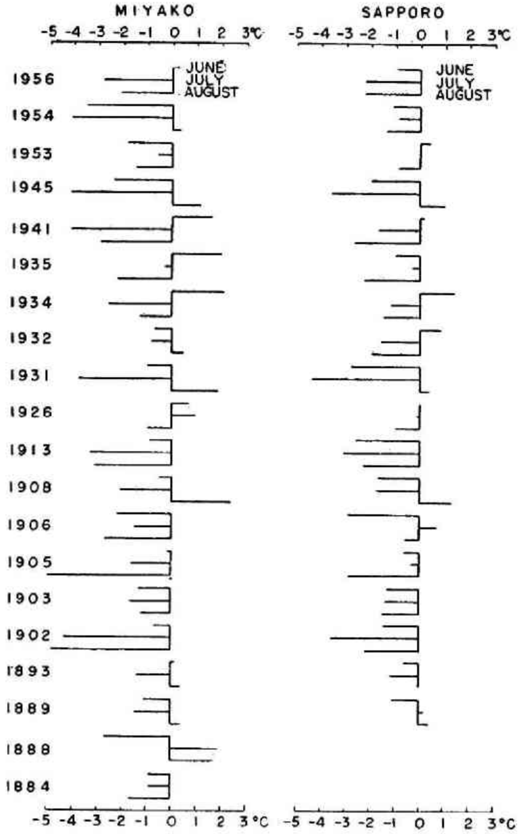


Fig. 1. Summer temperatures of the cool-summer years recorded. Figure shows the differences of monthly mean maximum temperatures in June, July and August with yearly mean temperatures.

pattern of the damage rate in every cool-summer year.

1 Cool-summer year

In a broad sense cool-summer damage can be defined as a phenomenon that farm management suffers economic damage caused by such accidents during the growing process of rice as low temperature or scanty insolation. On the other hand, the phenomenon of decrease in yield owing to low summer temperature is generally called cool-summer damage. To decide the year of cool-summer damage in the latter sense, we must distinguish the decreased yield or the decrease rate in a cool-summer year, from the yield of the normal year. However, here arise difficult problems how to make a distinction between a cool-summer year and the normal year, or as to the elimination of the decreased yield caused by cool-summer damage from that by other kinds of disaster. Although recently the degree of damages by causes is analysed and published by the Ministry of Agriculture and Forestry, the data by the same ministry are not available before 1952.

Therefore, we will take the cool-summer years recorded as such in the publications of meteorological disasters.[4]. Thus, the cool-summer years recorded in Hokkaido and Tohoku are twelve in number, and the years recorded only in Hokkaido are eight. The summer temperatures of the cool-summer years are shown in Fig. I. It is obvious that the temperatures are generally much lower than the mean summer temperature. But there are some differences among the temperatures of the cool-summer years themselves, and there are several types in the ways of appearance of low temperatures. The relation between the time in which low temperature appear and the growth stages of rice greatly influences the yield. Commonly, the following three types of cool-summer damages are pointed out[3]: I, Delay Type — the appearance of low temperature at the nutritive growth period of rice. 2, Impediment Type — the appearance of low temperature at the reproductive growth period of rice. 3, Combined Type — the appearance of low temperature at both periods.

The damages in the cool-summer years belonging to the Delay Type are comparatively slight, for there is a room for a recovering period after the appearance of low temperature, as seen in 1893, 1931, 1945, 1954 (Tohoku only). In the cases of the other two types, however, the damages are generally more severe than in the case of the Delay Type, as indicated by the Impediment Type — 1905, 1934, 1935 and the Combined Type — 1902, 1906 (Tohoku only), 1913, 1941, 1954 (Hokkaido only), 1956 (Hokkaido only).

Furthermore, there are types belonging to none of these three types, e.g. cool-summer damages accompanied with blight damage have occurred since 1934. Recently this type comes to appear in years when the damage of rice owing to low summer temperature is rather slight, as in 1953.

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4) Meteorological Observatory of Sendai (1951): Climate of the Tohoku District, 55–72.
Meteorological Observatory of Sapporo (1957): Climate of the Hokkaido District, Chapter 6, 1–24.
Exploitation Bureau of Hokkaido (1959): Study on the History of Cool-Summer Damage in Hokkaido, 1–101.

2 Cool-summer damage and difference-curves of yield

The average yield (koku per tan)* of rice in Japan has gradually increased from 1.04 koku in 1884 to 2.55 koku in 1960, and the distribution pattern of the yield in Japan has greatly changed, accompanying with the general increase.[5]. However, there are many minimum points on the curves showing the years in which the yields dropped for below the average (Fig. 2). The years showing these minimum points correspond, without exception, to the years in which some kinds of serious disasters broke out, such as typhoons, heavy rainfall, blight damage or low summer temperature. Particularly, marked minimum points appear, with few exceptions, in the cool-summer years. The fact shows that cool-summer damages in Northeastern Japan have greatly influenced the average land productivity of Japan even in recent years.

Fig. 2. Yearly change of average yield of rice in Japan (koku per tan).
(C : Cool-summer year recorded)

Next, we will pay attention to the yearly change of difference between the yield in each prefecture of Northeastern Japan and that of the nation as a whole (Fig. 3, 4). The difference-curves differ from each other in the degree of difference, rising tendency and flexibility. The curve of Hokkaido is most changeable and has the largest negative differences. The rising tendency is not so striking as on the curves. In Tohoku, the curve of Aomori Prefecture is most changeable, and that of Yamagata Prefecture generally has positive differences, and its rising tendency is clearest. The four difference-curves of Fukushima, Akita, Miyagi and Iwate Prefectures, have the tendency to make a positive difference rise in recent years.

In the case of Hokkaido, out of the twenty cool-summer years recorded in Hokkaido, fifteen years correspond exactly to the years showing the minimum

* 1 koku≒150 kg, 10 tan≒1 hectare, koku per tan × 1.5≒ton per hectare.

5) T. Noh (1961): Agricultural Problems in Tohoku (Northeastern Japan), Papers of Michigan Academy of Science, Arts, and Letters, Vol. XLVII, (1961 Meeting), 517–520.

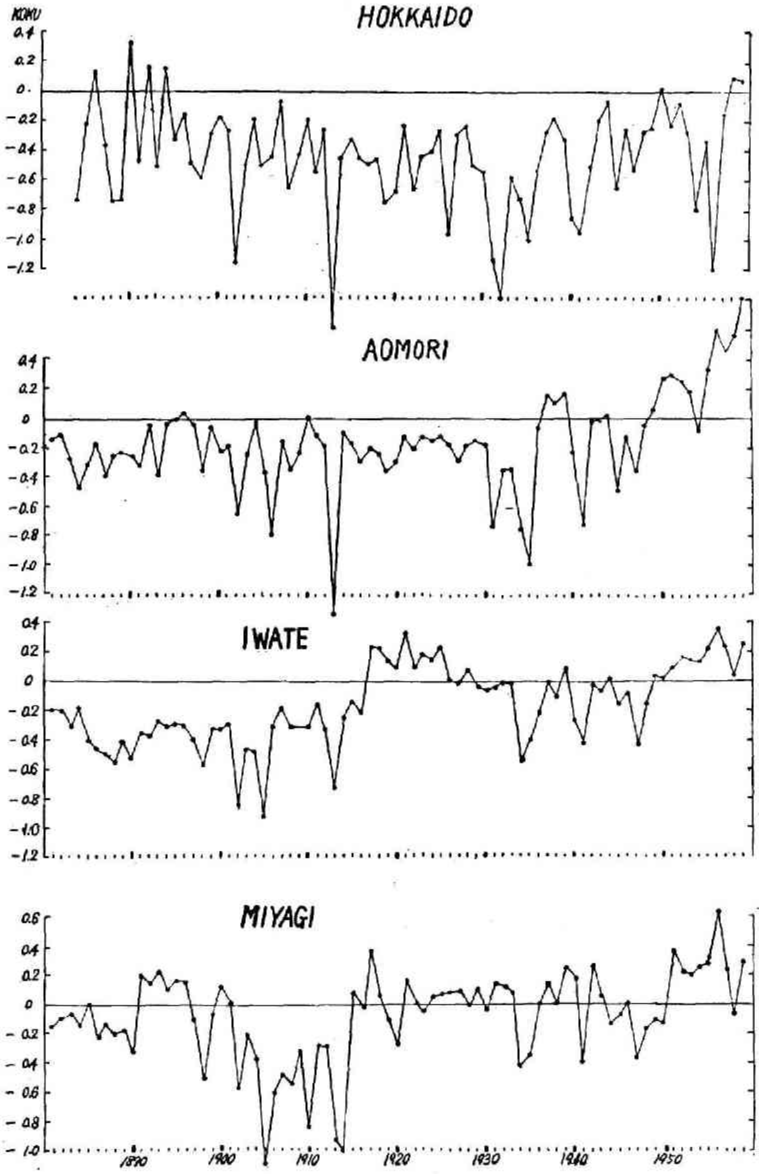


Fig. 3. Yearly change of difference between the yield in each prefecture of Northeastern Japan and that of the nation as a whole.

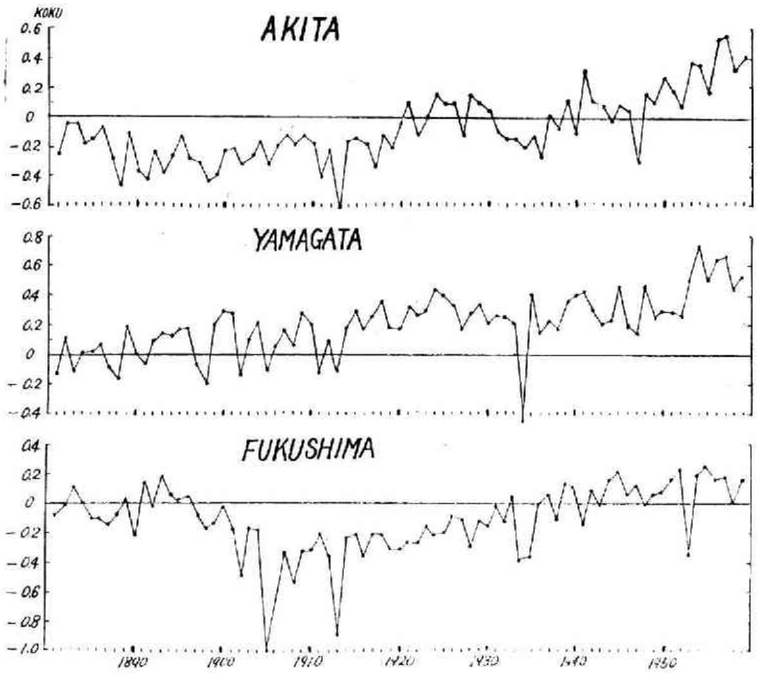


Fig. 4. Yearly change of difference between the yield in each prefecture of Northeastern Japan and that of the nation as a whole.

points on the difference-curve. In Tohoku, five (Yamagata Prefecture) to nine (Aomori Prefecture) years out of the twelve cool-summer years recorded in Tohoku are identical with the years showing the minimum points on the curves. One (Yamagata Prefecture) to three (Aomori Prefecture) years out of the eight cool-summer years recorded only in Hokkaido correspond to the minimum points.

In other words, the fact that the year showing the minimum point on a difference-curve corresponds to cool-summer year, is to enlarge the negative difference between the yield in each prefecture of Northeastern Japan and that of all Japan, owing to cool-summer damage. Therefore, from the analysis of the difference curves, it can be said that cool-summer damage has been more severe in Hokkaido and Aomori Prefectures than in the other prefectures of northeastern Japan, and that Yamagata Prefecture has suffered the slightest damage.

3 Damage rate in cool-summer year

In order to decide the decreased yield caused by low summer temperature, we must take the yield in the year free from the cool-summer damage as a standard.

But as a criterion we cannot take the yield in a single year, for it may have suffered the damage owing to other kinds of disaster. And when we take the yield in the year far from a cool-summer year, the criterion may differ greatly from the average land productivity of the time when the cool-summer damage broke out. Therefore, we will adopt as a criterion the average yield for the four years free from cool-summer damage, being respectively two years before and after a cool-summer year. That is, the ratio of decreased yield (D) to standard yield (S) is damage rate (R), as follows:

$$R = \frac{S - D}{S} \times 100$$

In the following chapters, we will consider cool-summer damages which broke out in and after 1888, for the statistical data before 1888 are not available. And when the cool-summer years appear in succession, the same standard yield is applied to calculate the damage rates of the years.

4 Distribution pattern of standard yield

A. Northeastern Japan by prefecture

The standard yields (koku per tan) of cool-summer years generally rose to 2.28–2.84 koku in 1956 from 1.04–1.57 koku in 1888 (Fig. 5). Especially, they greatly went up in the two periods of 1913–1926 and 1945–1953. The difference between the highest and the lowest yields was magnified to 0.63–0.78 koku in 1926–1941 from 0.56–0.61 koku in 1888–1913, and was reduced to 0.56–0.61 koku in 1953–1956. That is to say, the regional difference of the land productivity first turned to be magnified, and then has changed to be reduced in the recent time. In the case of Tohoku, the regional difference has become reduced to 0.24–0.40 koku since 1931.

Regarding the order of the standard yields in the prefectures, that of Yamagata Prefecture has been the highest since 1902, far leading the other prefectures. The yield in Hokkaido has ranked lowest since 1931. The yields in other prefectures have been between the two prefectures in the period of 1931–1954, and they were approximately on a level. However, the standard yield in Aomori Prefecture has kept the second rank since 1953, becoming close to that in Yamagata Prefecture. Thus, the order has recently changed.

B. Hokkaido district by subdivision unit

In 1902, the acreage of the rice-field in Hokkaido was about 10% of the present acreage[6], and we can take the data of the acreage in the nine subdivisions

6) H. Fukui (1961): Recent Changes in the Distribution of Rice Farming in Hokkaido, Sci. Rep. of Tohoku Univ., Seventh Series (Geography), No. 1;, 9–22.

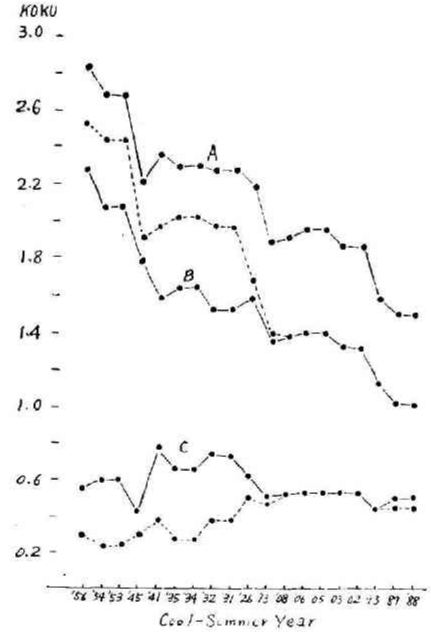


Fig. 5.

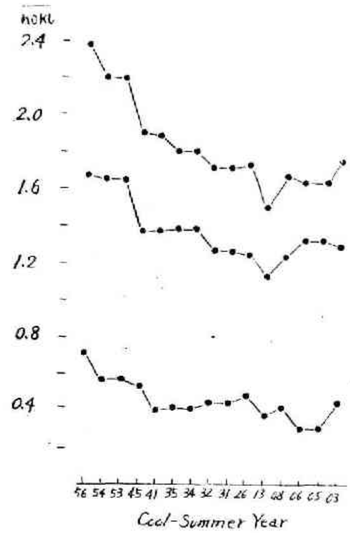


Fig. 6.

Fig. 5. The highest (A) and the lowest standard yield (B) of cool-summer years and the difference (C) between them in Northeastern Japan.
(The broken lines show the lowest yield and its difference in Tohoku)

Fig. 6. The highest and the lowest standard yield of cool-summer years and the difference between them in Hokkaido.

in 1903–1908, and in the eleven subdivisions since 1913. Therefore, the regional analysis of the damage rate distribution will be mainly done for the years after 1903.

In Hokkaido the standard yield increased to 1.67–2.37 koku in 1946 from 1.25–1.76 koku in 1903, and markedly rose after 1941 (Fig. 6). The difference between the highest and the lowest standard yields became greater from 0.35–0,48 koku in the period 1903–1941 to 0.52–0.69 koku in the period 1945–1956. We can say that the regional difference of land productivity has been magnified in recent time.

The tendency differs from those in Tohoku. If we can call this period of the low yields and the little regional difference the first stage of the regional development, the time showing the medium standard yields and the large difference will be the second stage, and the time with the high yields and the little regional difference the third stage. Therefore, the recent land productivity in Tohoku corresponds to the third stage, while Hokkaido belongs to the second stage.

5 Distribution of damage rates

A. Northeastern Japan by Prefecture

Strictly speaking, the damage rate may include the decrease-rate by any other kind of disaster, and to consider the damage rate distribution, it is necessary to pay attention to such influence.[7)]

There are marked difference among the distribution patterns of the damage rates in the nineteen cool-summer years. And it is difficult to recognize the general tendency of the damage rate distribution, from the simple comparison of them. Then, we sum up the numbers given to the orders of the damage rates, the number given being respectively 0, 1......6 or 7. O is given to the positive damage rate, 1 to the negative lowest and 6 or 7 to the highest. And we can take the frequency distribution of cool-summer damage as in Fig. **7**. The frequency of cool-summer damage may be roughly arranged in the following order; Hokkaido,

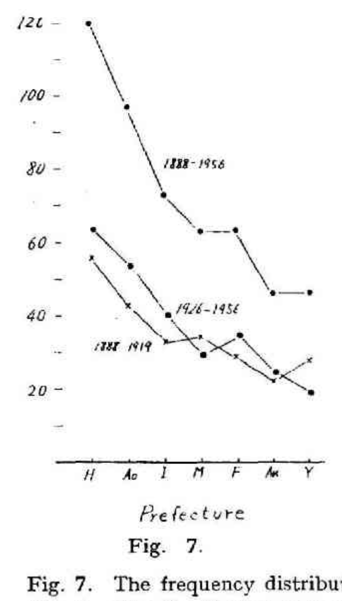


Fig. 7.

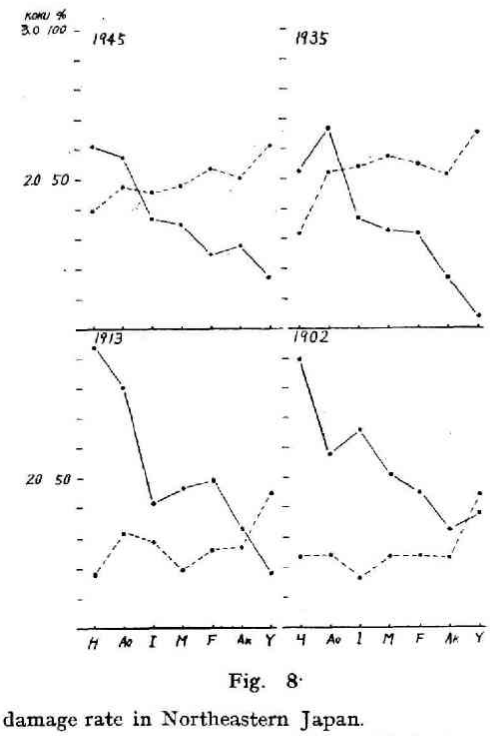


Fig. 8·

Fig. 7. The frequency distribution of damage rate in Northeastern Japan.
Fig. 8. The distribution pattern of damage rate (Type I) and standard yield (broken line) in Northeastern Japan.

7) According to the records presented by 4) and others, we will consider as follows.

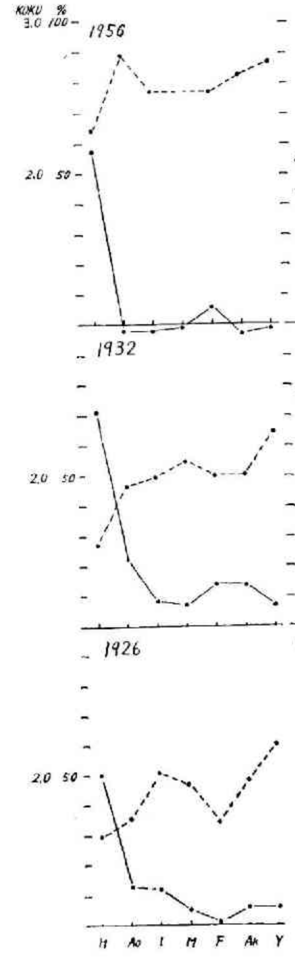
Aomori, Iwate, Miyagi, Fukushima, Akita, and Yamagata Prefectures. Then, the type showing the damage rate distribution is classified under Type I. Type II shows the distribution pattern in which the damage is focussed on the north, such as showing the markedly high damage rate either in Hokkaido or in Hokkaido and Aomori Prefecture, in comparison with the other prefectures. Next, Type III is the pattern belonging to neither Types I nor II.

It is surely difficult to draw exact boundaries among these three types, but it is possible roughly to classify the damage rate distributions into the types. Strictly speaking, the cool-summer years belonging to Type I are only 1945 and 1954, but if we admit some exceptional orders, the distribution patterns of 1902, 1913 and 1935 will belong to the same type. The prefectures showing the abnormal order, (Iwate and Yamagata in 1902, Fukushima and Miyagi in 1913, Aomori, Iwate, Miyagi and Fukushima in 1935) suffered the damages by typhoons or heavy rainfall, without exception. In the years of this type severe damage occurred all over Northeastern Japan, and the damage was particularly focussed on the Hokkaido district and the north and east parts of the Tohoku districts.

Type II may be more clearly identified than Type I, for example 1888, 1889, 1926, 1931, 1932, 1954 and 1956. As the characteristics of Type II, a fairly slight damage broke out in Tohoku, except in the case of 1931 and 1954 when severe damage occurred in Aomori Prefecture. The type appeared successively in the three periods 1888–1889, 1926–1932 and 1954–1956. But the difference of the damage rate between Aomori and Iwate Prefectures is not so great in 1954, and thus it is possible to make it belong to Type I, too. Type III contains various distribution patterns and most of them may have been deformed by other kinds of disaster. The cool-summer years of 1905 and 1934 are remembered as the years of the most severe cool-summer damage, together with 1902 and 1913. In 1905, the damage rates of Miyagi, Fukushima and Iwate Prefectures stood out conspicuously from those of other prefectures, but we cannot explain the reason sufficiently from only the slight flood damage recorded. Although there was a possibility of the outbreak of rice blight damage,[8] we cannot presume that it made the damage in those prefectures severe, because the chemical fertilizers which have much to do with the blight damage, were not so abundantly supplied at that time.

In the case of 1934, there were frequently flood damages in Yamagata, Iwate and Miyagi Prefectures, and severe blight damage was accumulated on the top of the cool-summer damage. In these two cases, the core areas of damage were in the

8) Fukushima Prefecture (1910): Cool-Summer Damage of Fukushima Prefecture in 1905, 1 ∼ 142.
Yamagata Prefecture (1951): Industrial Meteorology of Yamagata Prefecture, 92.



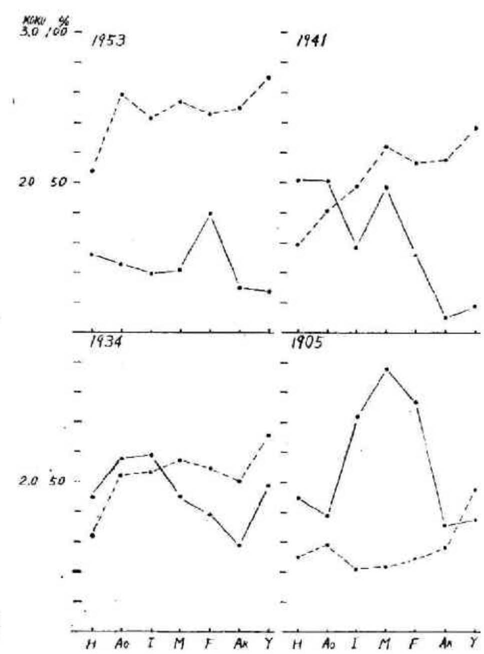


Fig. 10. (right) The distribution pattern of damage rate (Type III) and standard yield (broken line) in Northeastern Japan.

Fig. 9. (left) The distribution pattern of damage rate (Type II) and standard yield (broken line) in Northeastern Japan.

prefectures of Tohoku rather than in Hokkaido, and this is noticeable because it is entirely different from Types I and II. Particularly, rice blight damage combined with the low summer temperature can rather be regarded as cool-summer damage itself. In 1953, though the decreased yield under the low summer temperature was not so much, rice blight damage was very conspicuous in Fukushima Prefecture. The slight cool-damage years belonging to Type III are 1903, 1906 and 1953. The other kinds of disasters are unknown in 1893 and 1906, but in 1941, severe flood damages broke out in Miyagi and Fukushima Prefectures.

B. Hokkaido district by subdivision unit

According to the frequency distribution calculated in the same way as in the

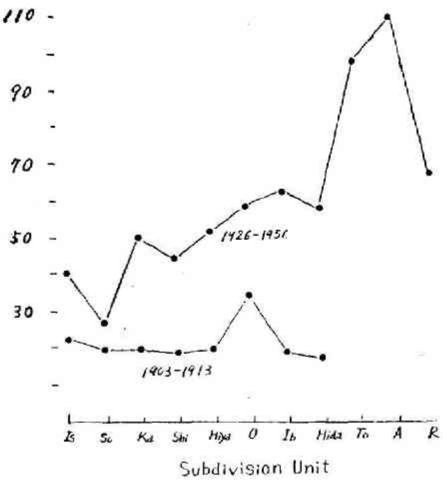


Fig. 11. The frequency distribution of damage rate in Hokkaido.

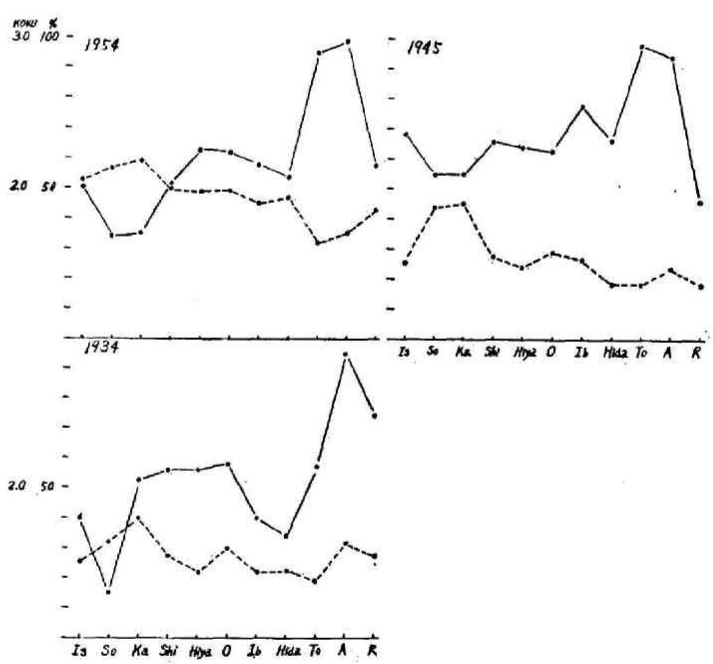


Fig. 12. The distribution pattern of damage rate (Type H·Ia) and standard yield (broken line) in Hokkaido.

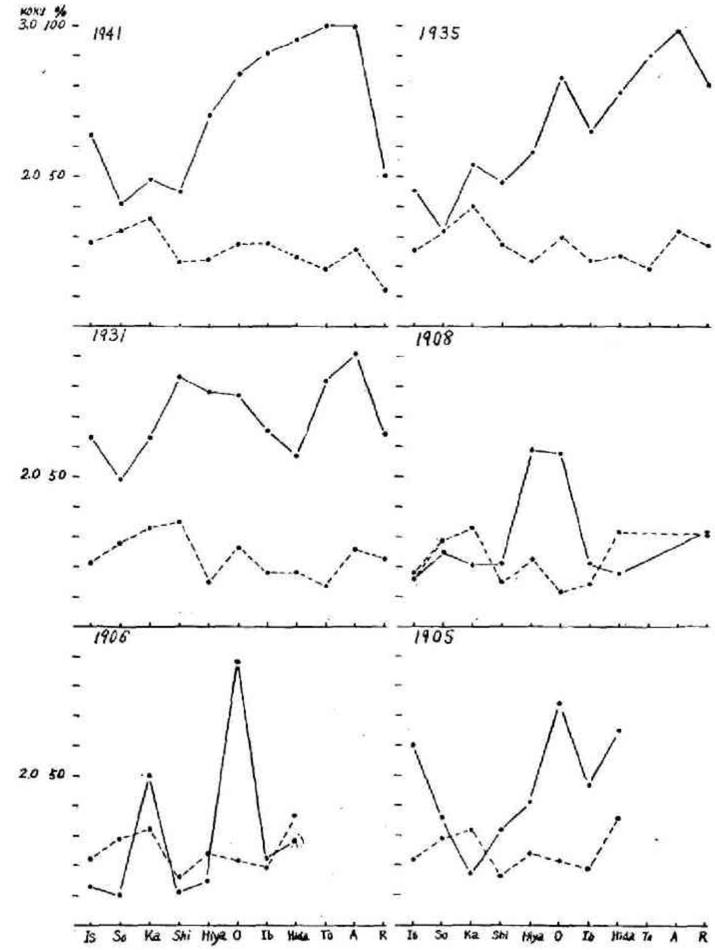
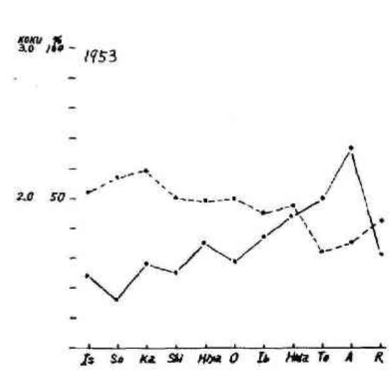


Fig. 13. The distribution pattern of damage rate (Type H · Ib) and standard yield (broken line) in Hokkaido.

Fig. 14. The distribution pattern of damage rate (Type H · Ic) and standard yield (broken line) in Hokkaido.



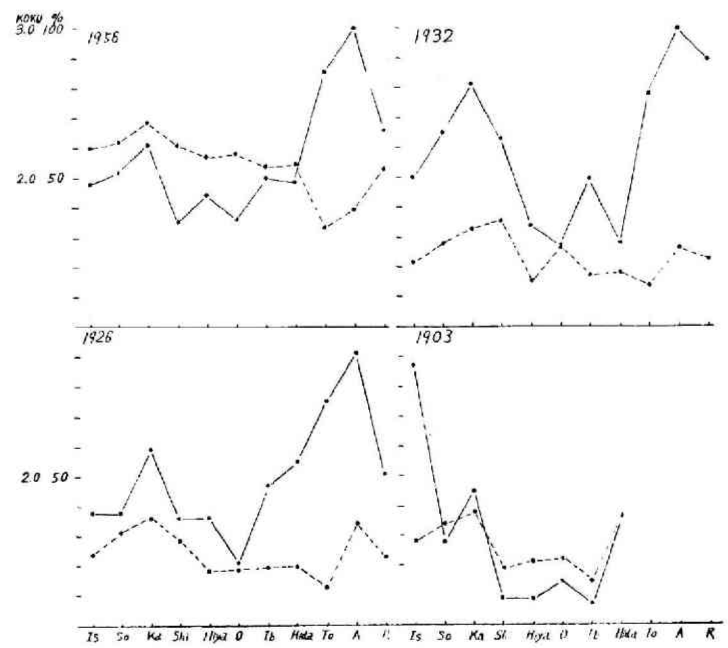


Fig. 15. The distribution pattern of damage rate (Type H·II) and standard yield (broken line) in Hokkaido.

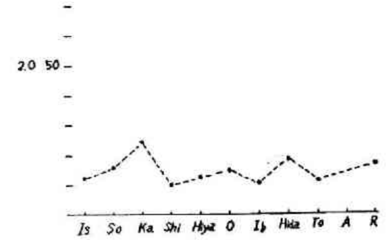


Fig. 16. The distribution pattern of damage rate (Type H·III) and standard yield (broken line) in Hokkaido.

case of Northeastern Japan, the regional difference is obsure in the period of 1903–1913, but it is distinct in the period of 1926–1956 (Fig. 11). In the latter period, the east part (Abashiri and Tokachi) of Hokkaido was the highest damage rate region, the central part (Sorachi) the slightest damage region, and the southern peninsula (Oshima) was the middle damage rate region. Especially, the damage rate of the

Table I. Classification of distribution patterns of cool-summer damage.

Cool-Summer Year	Northeastern Japan: Distribution Pattern of Damage Rates			Northeastern Japan: Other Kinds of Disasters[1]	Number of Prefectures	Hokkaido District: Distribution Pattern of Damage Rates					Hokkaido District: Other Kinds of Disasters[1]	Number of Subdivisions
	I	II	III			Ia	Ib	Ic	II	III		
1956		II			7				II			12
54		II		A: Wind & Flood Damage	7	Ia					South: Wind & Flood Damage	12
53			III	F·I: Blight Damage	7			Ic				12
45	I			A: Flood Damage	7	Ia						12
41			III	M·F·Y: Flood Damage	7		Ib					12
35	I			A·I: Flood Damage	7		Ib					12
34			III	Y·I·M·Ak: Flood & Blight Damage	7	Ia						12
32		II		M·I·Ak·F·Y: Flood Damage	7				II			12
31		II			7		Ib					12
26		II			7				II			12
13	I			M·I·Ak·F·Y: Flood Damage	7					III	Flood Damage	12
8			III	?	7		Ib					10
6			III	?	7		Ib					8
5			III	M·Ak·I: Flood Damage	7		Ib					8
3			III		7				II			8
2	I			Y·F: Flood & Wind Damage	7					III		4
1893			III	?	7							2
89		II			7							2
88		II			7							2

1) Other kinds of disaster which modified the classification.
A: Aomori Prefecture, I: Iwate Prefecture, M: Miyagi Prefecture, F: Fukushima Prefecture, Ak: Akita Prefecture, Y: Yamagata Prefecture.

east part was the highest in all the cool-summer years.

Then, the distribution pattern belongs to the Type H·Ia as the fundamental pattern, for instance 1954. But the difference between the damage in the central part and that in the southern peninsula becomes greater as in 1941 (Type H·Ib), and less as in 1953 (Type H·Ic). Furthermore, there are other two types in which the central part shows the higher damage rate than in the southern part (Type H·II) as in 1956, and there was little difference among the three parts (Type H·III) as in 1913 when their damage artes were over 70%. The types of the damage rate distribution in every cool-summer year are shown in Table I.

The Type H·I similar to the standard type appeared most frequently, above all Type H·Ia and H·Ib. The pattern clearly classified as Type H·II took place three times and the pattern under Type H·III only twice. Moreover, the other kinds of great disaster which influenced the damage rate broke out in the five cool-summer years, but we can guess that the disaster which modified the classification broke out only in two years, as the flood damage in the central part in 1932, and the wind damage (typhoon) in the southern peninsula part in 1954.

C Comparison of the distribution patterns of Northeastern Japan and Hokkaido

Table II shows the types of Hokkaido in comparison with the types of Northeastern Japan. The following characteristics will be found. The two cool-summer years belonging to Type H III coincide with the years of Type II, both having the severe damage prevailed.

Table II. Comparison of the distribution patterns of Northeastern Japan and Hokkaido

		Northeastern Japan		
		Type I	Type II	Type III
Hokkaido	Type H·Ia	1945	1955	1934
	Type H·Ib	1935	1931	1941 1908 1906 1905
	Type H·Ic			1953
	Type H·II		1956 1932 1926	1903
	Type H·III	1913 1902		

Three years out of the four years of Type H·II, belong to Type I. If Type III of 1903 is excepted owing to the slight damage of under 25%, we can say that Type H·II having the high damage rate region in the east and central parts of Hokkaido appears when the damage was focussed on the north part of Northeastern Japan (Type I). Type H·I being the standard type of Hokkaido corresponds to all types of Northeastern Japan. But close observation reveals that Type H·I seems to appear rather frequently when Type II prevails, if we could except 1908 having slight damage and classify those of 1934 and 1941 into Type II, discriminating the damages by other disaster from the damage rate.

Seeing from the types of Northeastern Japan, Type I in three years out of the five years corresponds to Type H·II, and Type III roughly to Type H·Ib. Type I being the standard type of Northeastern Japan corresponds to all types of Hokkaido.

6 Summary

The paper is a part of the study to clarify the stability of the rice agricultural region in Northeastern Japan, through the regional analysis of cool-summer damage. Its purpose is to make clear the influences of cool-summer damage on the land productivity, and the distribution pattern of the damages in Northeastern Japan.

For this purpose, he has analysed the relations between the cool-summer year and the yearly change of yields in all Japan or the difference-curves of Northeastern Japan. Next, he has taken the damage rate distributions in Northeastern Japan by prefecture and those of Hokkaido by subdivision, and has classified them into some distribution patterns, based on the frequency distribution of the damage rate. The results obtained are as follows:

1. In the records of meteorological disasters, twenty cool-summer years are recognized in Northeastern Japan since 1884. Out of them, eight years are only for Hokkaido. But out of the eight years recorded, one or three years can be recognized as a cool-summer year in the prefectures of Tohoku in the difference-curves.

2. Cool-summer damage still has great influence on the land productivities on Japan. Hokkaido has most frequently suffered from the damage, Aomori Prefecture comes next to Hokkaido, and then comes Yamagate Prefecture last.

3. According to the yearly change of the standard yield, the regional development of land productivity has been in the third stage in Tohoku since 1931, and in the second stage in Hokkaido since 1945.

4. We can recognize three types (I, II, III) of the damage rate distribution in Northeastern Japan, and five types (H·Ia, H·Ib, H·Ic, H·II, H·III) in Hokkaido, according to the classification based on the standard type of the frequency distribution. And the correspondences between the types of Northeastern Japan and those of Hokkaido are particularly recognized between Type II and Type H·III, and Type I and Type H·II.

5. The other kinds of disaster modifying the classification, are recognized in five years in Northeastern Japan and in two years in Hokkaido, though it is impossible exactly to determine the degree of the influence.