KY85—10—1

论 文 汇 编

项目领导小组

KY85-10-01课题发表在各杂志上的论文目录

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THE EFFECTS OF WATERLOGGING CALAMITY ON THE RICE OUTPUT IN THE AREA OF MIDDLE AND LOWER REACHES OF THE YANGTZE RIVER

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Middle - and - lower reaches of the Yangtze River are located in the middle of China. The climate there is subtropical moist monsoon. The area is consisted of six provinces (Hunan, Hubei, Zhejiang, Jiangxi, Jiangsu and Anhui) and one municiplity (Shanghai) . Its cultivated area covers 201. 1 million hectares, making up 21 % of the national total cultivated area. Its annual grain yield is 142. 98 million tons, amounting to 32% of the national total grain yield. Among them, the rice yield is 103. 93 million tons, taking up 73% of the grain yield in that area and 55% of the national total rice yield. It is the major rice production base of China. The middle - and lower reaches of the Yangtze River are one of the waterlogging areas of China. According to incomplete statistics, its average waterlogged area a year is 1. 68 million hectares, the grain loss due to floods is 115 billion kilogram, amounts to 40% of the national total grain losses. Mr. Huang Chaoying et al. have analyzed the rice ourputs in typical waterlogging years of some provinces and cities in the area of middle - and - lower reaches of the Yangtze River, and found out that rice production is more sensitive to floos than to drought.

This paper gives out detailed analyses on the effects of waterlogging on rice output and discussion of relations of rice output fluctuated with rainfalls, based on the material of rice output (average per mu • yield of one - harvest rice and double - harvest rice) and rainfalls in the key period of rice growing (from April to October) for provinces and cities in the area of middle - and - lower reaches of the Yangtze River. 61 stations are selected in the area for analyses, that is one station in Shanghai, 10 stations in Jiangsu, 6 stations in Zhejiang, 10 stations in Anhui, 13 stations in Jiangxi, 12 stations in Hunan and 9 stations in Hubei.

I . Output Fluctuation and Waterlogging Calamity

Meteorological output refers to fluctuating part of rice output changes which is caused by the changes of weather and climate. It is expressed in the following formula:

• 1mu = 1/15ha.

$$Y = Y_t \quad Y_{t_t} \qquad (\text{I} .1)$$

$Y$is meteorological output. Y_t is actual output. Y_t is tendency output. In this article, section linear fit method is used to calculate the tendency output, which gives out a relatively more objective result. The fit of tendency output is given out in Fig. 1.

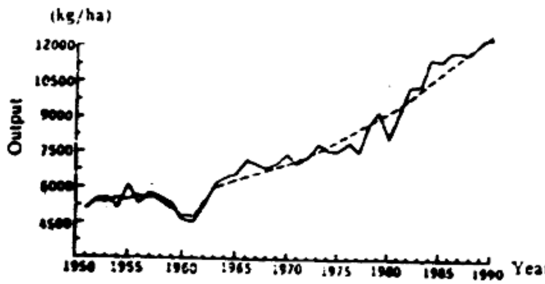

Fig. 1 Simulation of rice output in the area of middle - and - lower reaches of the Yangtze River

(Continuous line stands for actual output and dotted line stands for tendency output.)

When relative meteorological output (meteorological output/tendency output) is less than - 5 percent, the year is considered as a poor year. When it is greater than 5 percent, the year is considered as a good year.

From 1951 to 1990, during the 40 years there were 6 poor years (year 1954, 1956, 1951, 1975, 1977 and 1980), the average rate is one poor year in every 7 years. In 1980 and 1977, the average loss was more than 10 percent in the area, the meteorological output was - 1,113.0kg/ha, and - 943.5kg/ha, respectively. We suffered from the heaviest loss in these two years during the 40 years. Next to this, was the year 1954. Its meteorological output was - 456.0kg/ha, decreased 8.4%. In 1980, all the 7 provinces and cities in the area suffered output reduction. The reduction reached 20 percent in Shanghai and Anhui provinces. The year 1977 was also a poor year for the area: the reduction was 26 percent in Jiangsu province, and 10 percent in Zhejiang, Anhui and Hunan provinces. The year 1954 was another poor year for the area: the reduction reached 15 percent in Anhui province. It was also the province who had suffered the heaviest loss in the area.

If we contrast and analyze the precipitation and the anomaly from April to October in the good years of rice grain with that in the poor years in the middle - and - lower reaches of the Yangtze River (Table 1), we can see that from 1951 to 1990, in the six poor years, the average meteorological output is - 600kg / ha, the average precipitation from April to October is 1, 130 mm, it is 17% more than that in normal years. In the six good years, the average meteorological output is 630kg/ha, precipitation is 852 mm, it is 12% less than normal years. The precipitation from April to October in the poor year is 278 mm more than that in the good year. Except for the year 1961, the precipitation are all positive anomaly in the five years. In contrast, the precipitation from April to October are less in good years. According to test to precipitation anomaly in good years and in poor years, it is found out that there is a great difference in precipitation between good years and poor years through obvious standard test of $\alpha = 0.01$.

Table 1 Contrasting Analysis on Precipitation in Good Years and in Poor Years for Rice Growth in the Middle - and - Lower Reaches of the Yangtze River

Poor Year	Meteorological Output (kg/ha)	Relative Meteorological Output (%)	Precipitation (mm)	Precipitation Anomaly (%)
1954	-468.0	-8.4	1361	40
1956	-375.0	-6.6	1097	13
1961	-268.5	-5.6	941	-3
1975	-439.5	-5.5	1153	19
1977	-943.5	-11.2	1123	16
1980	-1113.0	-12.2	1106	14
Average	-600.0	-8.3	1130	17
Good Year	Meteorological Output (kg/ha)	Relative Meteorological Output (%)	Precipitation (mm)	Precipitation Anomaly (%)
1955	541.5	9.8	873	-10
1966	676.5	10.5	753	-22
1967	337.5	5.1	774	-20
1984	1026.0	9.8	933	-4
1985	589.5	5.5	909	-6
1986	580.5	5.2	868	-11
Average	630.0	7.7	852	-12

when precipitation anomaly is bigger or equal to two standard δ, the year is considered as a severe waterlogging year; when precipitation anomaly is bigger or equal to one standard δ, it is considered as the criteria for waterlogging disaster. For the past 40 years, there were nine waterlogging years (1954, 1956, 1962, 1969, 1973, 1975, 1977, 1980, 1985) in the area of middle - and - lower reaches of the Yangtze River, and the climate probability was 23%. Averagely, there was one waterlogging year in every four to five years. In the nine years, except for the year 1969, 1973, 1983, there was reduction of output in various degrees in the rest six years. In five years, reduction of output took up over 5%, reaching the standard of poor year. In 1954, there was the most severe waterlogging disaster for the past 40 years. In that summer from June to August, precipitation was 75% more than that in normal years. The standardized variable of precipitation reached 3.7, causing output reduction in the whole area. Meteorological output in Anhui and Hubei provinces were -690 kg/ha, -870 kg/ha respectively, with output reduction over 15%. The year 1980 was another severely waterlogging year. Precipitation anomaly from June to August was more than 2 δ, and the average output reduction was 12% in the whole area. Moreover, although averagely there was no output reduction in the whole area in the waterlogging years 1969, 1973 and 1983, there was a short fall in output of various degrees in some provinces and cities. For example, in 1969 rice grain output in Anhui and Hubei provinces reduced by over 5%; in 1973 output in Jiangxi and Hunan provinces reduced by 5%; in 1983, meteorological output in Shanghai was −885kg/ha, and its output reduction was 8%.

If we look far back into the rice output fluctuation of the past 40 years, we can see that averagely there was an output reduction year in every six to seven years, and moreover, precipitation was more in the period of rice growing from April to October in poor years. 83% (5/6) of these poor years reached the standard of waterlogging. There was average one calamity in every four to five years, causing output reduction of various degrees in the whole area or in some provinces or cities. In 56% (5/9) of waterlogging years, rice output reduction was more severe. From this we can see that there was always waterlogging calamity in the poor years in the middle − and − lower reaches of the Yangtze River. Most of the waterlogging years caused rice output reduction. There was a close relationship between the two.

II . The Relationship Between Rice Output and Precipitation

In order to further reveal the relationship between rice output and precipitation in the area of middle − and − lower reaches of the Yangtze River, this paper calculated the relevant coefficient of monthly precipitation from April to October with meteorological output of rice grain. It is found out that meteorological output all has a negative correlation with the precipitation from April to October, and from June to August in provinces and cities of the middle − and − lower reaches of the Yangtze River. As far as rice output in the whole area is concerned, relevant coefficient between meteorological output and precipitation in August, from June to August and from April to October has passed the obvious standard test of $\alpha = 0.05$, and meteorological output has the closest relationship with the negative correlation of precipitation from April to October. Moreover, the relevant coefficient between meteorological output in Shanghai Municipality, Zhejiang and Hubei provinces and precipitation from April to October has also passed obvious test.

It can be seen from the simulated equation of fluctuation of meteorological output with the changes of total precipitation from April to October (Fig. 2), meteorological output always reduces with the increase of precipitation in the provinces and cities (except for Jiangxi province) in the middle − and − lower reaches of the Yangtze River.

The simulated equation is as follows:

$$\text{The whole area: } Y = -1.1055X + 966.0, \qquad (\text{II} . 1)$$

Shanghai: $Y = -1.3215X + 1272.$[illegible] (Ⅱ.2)

Jiangsu: $Y \quad -1.2660X + 1143.0.$ (Ⅱ.3)

Zhejiang: $Y = -0.9135X + 1045.5.$ (Ⅱ.4)

Anjui: $Y = -0.6585X + 615.0,$ (Ⅱ.5)

Jiangxi: $Y = -0.0180X + 4.5,$ (Ⅱ.6)

Hubei: $Y = -0.8700X + 871.5,$ (Ⅱ.7)

Hunan: $Y = -0.3615X + 319.5.$ (Ⅱ.8)

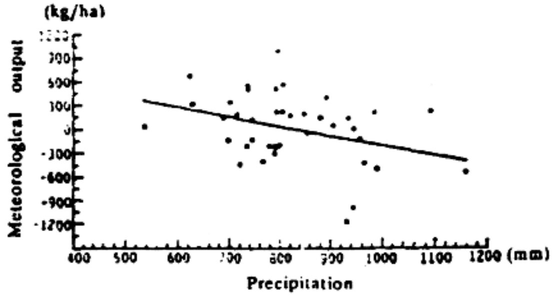

Fig. 2 Rice output fluctuates with precipitation and its simulation
(Straight line stands for simulated line)

Averagely speaking from the whole area, every increase of 100mm precipitation from April to October, causes an average output reduction of 111.0kg per hectare. The variance of mqteorological output of the past 40 years is calculated as 324.0 kg, that is if precipitation changes by 100 - 200mm, it can normally cause fluctuatuin of meteorological output by 30 - 60%. This further shows that the change of precipitation is the major factor to cause annual change of rice output.

Ⅲ. The Effects of Climate Change on Rice Output

From the precipitation from April to October of different decades in the seven provinces and cities in the area of middle - and - lower reaches of the Yangtze River, we can see that the precipitation changes of different decades in the seven provinces and cities are quite identical. Approximately there was less precipitation in the sixties and seventies, and there was more in the fifties and eighties. For the past 40 years, precipitation changes experienced a change cycle of more - less - less - more, with very typical change stages.

If we make a running mean of ten years for precipitation anomaly percentage from April to October and meteorological output, we can further study the effects of meteorological changes on rice output. For the past 40 years, there were typical stage changes in precipitation form April to October in most provinces and cities in the middle - and - lower reaches of the Yangtze River Meteorological output roughly experienced more than one cycle of sine function. The phase of output change is basically opposite to precipitation. Averagely speaking from the whole area, in the first 20 years, precipitation was first reduced and then increased, while meteorological output was increased first and then reduced. Precipitation trough was located in the year of 1967, which was just the peak of output fluctuation. In the second 20 years, the change tendency of precipitation was not typical, in the seventies rice output followed the tendency of reduction, while in the eighties, rice output followed the tendency of increase.

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从农业需水量评价我国的干旱状况*

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提 要

利用全国160个站点1951～1990年40年的月平均温度和降水量资料,计算了历年逐月(季、年)的农业需水量、湿润指数和积分湿度指标,并对我国农业水分满足程度和四季干旱情况进行了分析.

关键词:干旱;积分湿度指标;湿润指数.

干旱是气候灾害中最严重的灾害,因其出现频率高、持续时间长、波及范围大、对国民经济特别是对农业生产有严重不利的影响,故历来被人们关注.但由于学科或应用领域不同,衡量干旱的标准也不统一[1].本文定义了一个定量而又比较简单的方法——积分湿度指标[2],并依此评价我国的农业干旱状况.

1 积分湿度指标计算方法

积分湿度指标:

$$I = \sum_{i=1}^{n} K \cdot T_i / \sum_{i=1}^{n} T_i \tag{1}$$

式中,I 为年内月平均气温 >0℃时期的积分湿度指标,用百分数表示;T_i 为月平均气温;n 为月平均气温 >0℃的月数;K 为月湿润指数.

$$K = R/0.16\sum t \qquad (K \leqslant 1.0) \tag{2}$$

式中,R 是月降水量;$\sum t$ 是 >0℃的月积温,用月平均气温乘当月日数求得.R 代表供水量,$0.16\sum t$ 代表需水量.系数0.16是根据灌溉试验资料和文献[2、3]确定的,在干旱地区和干旱季节,此系数值可酌情稍取大一点,在湿润地区或相对湿度大的时期,此系数可

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取小一点，为便于在大范围内进行比较，本文统一取 0.16. $K=1.0$ 表示农业水分供需平衡，$K<1.0$ 表示干旱，$K>1.0$ 表示供大于求. K 值愈小表示愈干旱，该值由小到大的逐渐变化，说明农业用水依次得到满足，它代表地区实际水分供应的客观规律.

取 $K\leqslant 1.0$，主要考虑到作物对水分的要求并非越多越好，而是有个适宜界限，即水分供需平衡（$K=1.0$）. 在其他条件都得到满足的情况下，适宜的水分条件对作物的生长发育最有利，过湿润条件对作物生长不但起不到良好的作用，还有可能出现水涝灾害.

$T_i/\sum_{i=1}^{n}T_i$ 是作物可能生长时期的热量分布规律，实质上，它反映了农业生产期间耗水量变化的规律性，也就是说，它是农业生产期间各月耗水量（需水量）的权重因子.

2　农业水分满足程度 —— 积分湿度指标 I 的分析

图 1 是 1951 ～ 1990 年的平均积分湿度指标. 由图 1 看出，积分湿度指标 I 自东、南向西、北逐渐减小，表明我国自然降水对农业水分需求的满足程度在这个方向上越来越低. 在贝勒庙 - 包头 - 兰州一线以西，除高山区外，I 值均小于 50%，故本文暂不讨论. 此线以东和以南地区及青藏高原东部，I 值大于 50%，表明农业水分供应条件较好，为可旱作农业区.

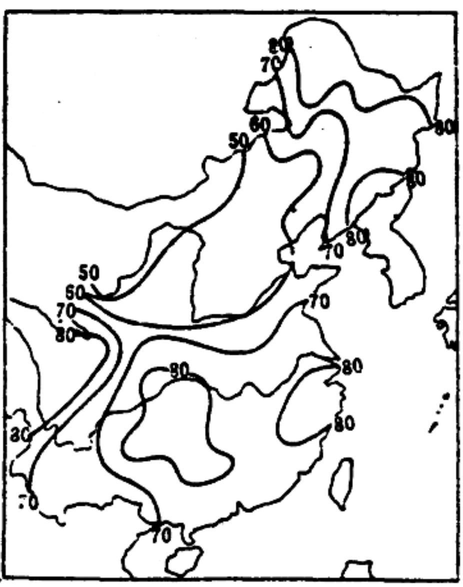

图 1　积分湿度指标 I(%)

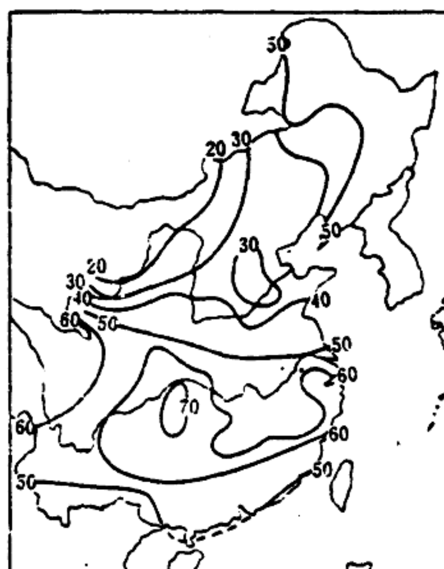

图 2　最小积分湿度指标 I_{min}(%)

在 I 值大于 50% 的地区，其中江南东部和西部、东北北部和长白山区以及西南地区的西部和青藏高原东部部分地区的 I 值在 80% 以上，是全国农业水分满足程度最高的地区. 华北大部和黄土高原东部的 I 值在 50% ～ 60% 之间，是旱作农业区中水分供应条件

较差的地区.其他地区的 I 值为 60% ~ 80%,都有不同程度的干旱出现.

特别是在少雨年,农业缺水更多,干旱更为严重.图2是1951 ~ 1990年各地出现的最小 I 值.由图2可见,淮河至秦岭以北广大地区的 I_{min} 值,除东北北部和东南部大于50%外,其他地区均小于50%,部分地区更小(< 30%).在淮河至秦岭以南广大地区,除个别地区外,I_{min} 值均小于70%,其中云南和广西南部及华南沿海地带的 I_{min} 值在50%以下.江淮地区、江南北部、华南大部、西南南部和四川盆地的 I_{min} 值为50% ~ 60%.甚至在我国气候最湿润的江南南部和西部以及西南地区东北部,其 I_{min} 值也只有60% ~ 70%,与黄淮地区的多年平均值相当,农业用水的满足程度相差多达30% ~ 40%.

3 四季干旱频率分析

为了分析四季的干旱状况,我们统计了各地1951 ~ 1990年逐年逐月的湿润指数 K,然后按春(3 ~ 5月)、夏(6 ~ 8月)、秋(9 ~ 11月)、冬(12 ~ 2月)计算季湿润指数和各级干旱出现的频率.干旱等级划分结果如表1所示.

表1 按季 K 值划分的干旱等级

K 值	干旱等级	干旱程度
≥1.00	0	无旱
0.76~0.99	1	轻旱
0.51~0.75	2	中旱
0.26~0.50	3	重旱
≤0.25	4	严重旱

图3a是2级以上春旱频率分布图,由图看出,淮河至秦岭以北地区(除东北北部和东、南部)频率大都在50%以上,其中华北大部和东北的西南部大于75%.江南大部和华南北部春旱频率为零,但西南地区南部频率大于50%,其中云南大部和四川南部部分地区则大于75%.华南大部和江淮地区以及大兴安岭北部和长白山地区频率均在25%以下,其他地区在25%~50%之间.

图3b表明我国东、南部,除个别地点外,夏旱频率均在25%以下,其中西南地区大部、青藏高原东部、华南南部以及大兴安岭和长白山地区频率为零.华北西部和北部以及黄河中游地区频率为25%~50%.

图4a是2级以上秋旱出现频率分布.由该图看出,秋旱分布最广,除四川西北部部分地区频率为零外,全国其他地区均出现过中等以上的秋旱.频率在50%以上的地区有华北大部、黄淮地区和华南北部,其中华北平原大部和西辽河平原频率大于75%.而淮河至秦岭以南大部地区及青藏高原东部频率在50%以下,其中西南地区西部、四川东部和两湖西部及华南沿海和江南东部沿海频率小于25%.内蒙东北部和东北北部及东南部频率也小于25%.其他地区在25%~50%之间.

图4b是2级以上冬旱出现频率分布.由该图看出,冬旱主要分布在华南南部和西南地区,频率大于50%,其中四川东南部、云南大部、两广西南部和海南地区频率在75%以

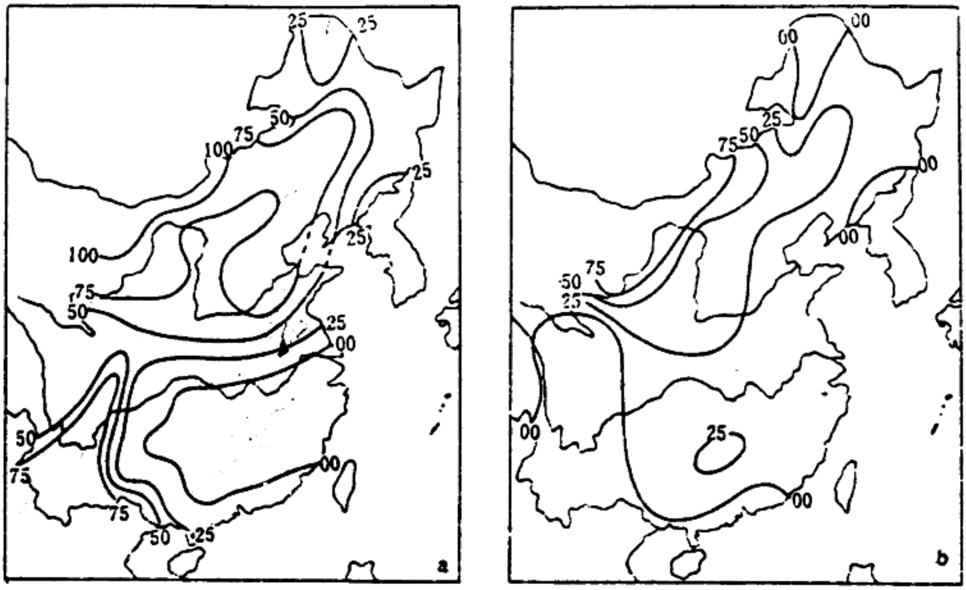

图3　2级以上春旱(a)夏旱(b)($K\leqslant0.75$)的频率(%)分布

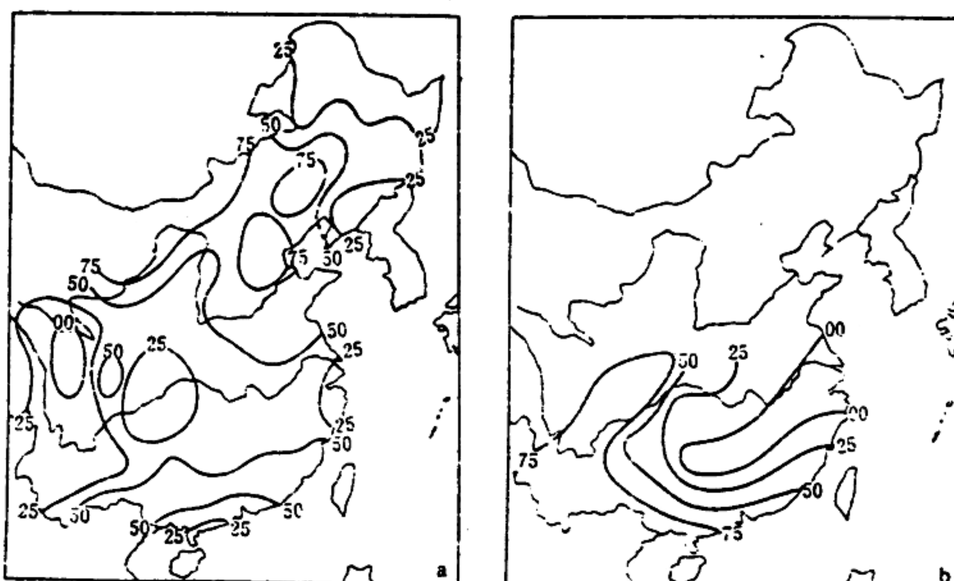

图4　2级以上秋旱(a)冬旱(b)($K\leqslant0.75$)的频率(%)分布

上，江淮和江南地区频率在25%以下，其中江南中部和东北部近40年来基本上未出现中等以上的冬旱. 其他地区频率在25%～50%之间.

4 结 语

用积分湿度指标和季湿润指数评价自然降水对农业需水的满足程度和干旱，比较简单、客观和定量，并可在大范围内进行比较．但这个方法只适用于月平均温度大于0℃的时期，难以用来评价我国北方冬季之干旱状况．另外，当月平均温度值很低时，如降水稍多，得出的 K 值可能很大，在这种状况下，也需要对 K 值做些调整．

本文初次用这种方法评价我国的干旱情况，有些问题还需要做进一步深入讨论．

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THE ASSESSMENT OF AGRICULTURAL DROUGHT CONDITION FROM FARM WATER REQUIREMENT

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Abstract

In this paper, farm water requirement, moisture index and integrated moisture index are computed for every month, season and year by using the data of monthly rainfall and temperature for 160 stations in East China during the period of 1951～1990. And, the profit and loss of farm water requirement and drought condition for seasons in China are analysed.

Key words: Drought; Integrated moisture index; Moisture index.

近40年我国夏季旱涝变化及其成因初探

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提　要

本文利用1951—1990年全国336个测站夏季(6—8月)降水资料和太平洋海表面温度来分析我国近40年夏季旱涝分布的变化及其成因。分析结果表明：我国夏季降水在1965年前后发生了一次气候跳跃，我国北方(包括华北和东北)从1965年后夏季降水明显减少，干旱化的趋势明显，这种趋势与西非萨赫勒地区干旱化的趋势相似。分析结果还表明我国80年代的气候与70年代的气候有较大差别，长江、淮河流域从70年代末起降水增多，涝灾明显增多；而华南和华北在80年代降水明显比70年代少，干旱趋势加重。

上述所发生的气候变化主要是由于80年代赤道东、中太平洋明显增温，而西太平洋暖池热容量明显减少所造成。这种现象似如一个年代际的"ENSO现象"，它对全球气候变化将会有较大影响。

一、引　　言

众所周知，全球增暖及其对环境、水资源和粮食生产等的影响已是世界科学界日益重视的重要科学问题之一，它已是各国政府作经济和社会决策必须认真考虑的重要问题。

关于全球气温变化，Hansen[1]已有较详细的分析，他发现在最近100年全球气温平均上升了0.8℃。特别是从19世纪70年代末到现在，大约气温上升了0.3℃。Bradley等[2]比较了我国气温变化与北半球气温变化的异同，他们的研究表明，我国的气温变化总的趋势是与北半球的趋势一致，但从年代际的变化来看，这两者也有些差别。他们的结论与《中国气候蓝皮书》中的分析结果是一致的。最近，陈隆勋等[3]利用全国160站的气候资料分析了我国气温的变化，他们的结果表明，我国北方包括华北、东北和西北最近39年来气温上升，但在我国江淮地区和四川等地，气温下降。

关于气候变化，正如上面所述，许多研究主要集中讨论全球和我国气温的变化。但由于我国是季风气候，气候变化更多表现在降水的变化。黄荣辉和张庆云[4]从我国夏季降水的变化来讨论我国气候变化及对水资源的影响，但只用了我国60个站的地面气候资料。为了更深入和详细地讨论我国夏季气候的变化，我们应用全国336个测站1951—1990年夏季6—8月的旬降水来讨论我国旱涝分布的变化。并且利用1951—1990年太平洋海表面温度(SST)和西太平洋暖池沿137°E次表层海温分布来讨论我国夏季气候变化

的可能成因。

二、资　　料

1．降水资料

由于我国处于东亚季风区，降水的气候振荡要比气温的振荡复杂得多。为了详细说明我国各区域夏季降水的变化，把全国336个测站按图1所示，根据地理环境和气候特征划分成7个区域。1区是黄河流域和华北地区，包括了40个测站；2区是江淮流域，包括了28个测站；3区是长江中下游流域，包括了45个测站；4区是华南地区，包括了35个测站；5区是东北地区，包括了35个测站；6区主要是西北地区，包括了58个测站，此区是降水少于200mm的干旱区；7区是西南地区，包括了55个测站。

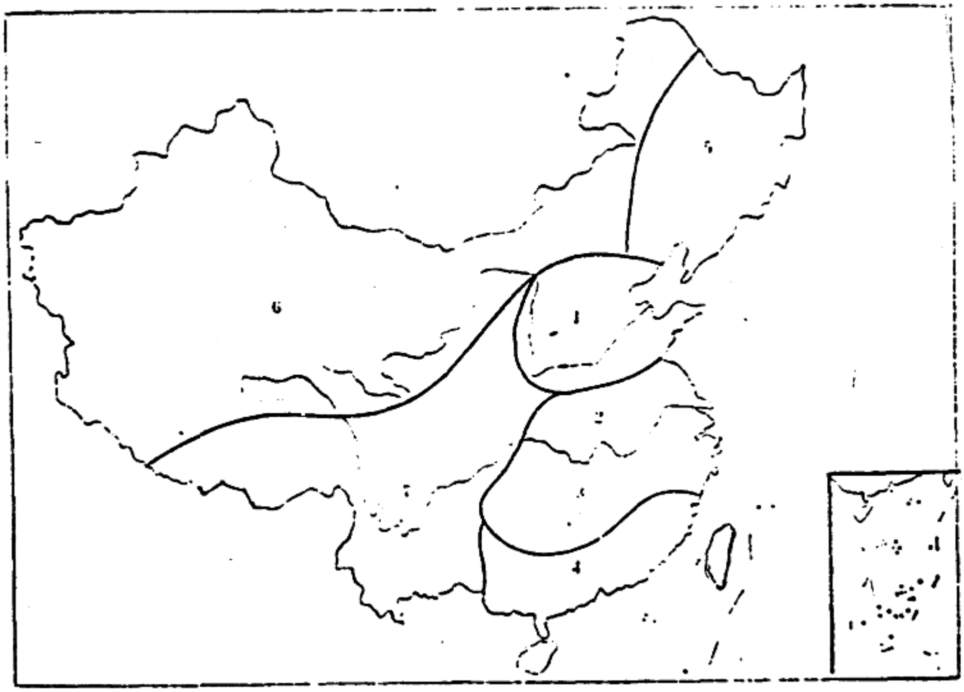

图1　我国旱涝分区图

2．海温资料

本文采用1951—1988年CODAS中SST资料以及西太平洋暖池沿137°E从50—400m深次表层ST资料。

三、我国各区域夏季降水异常的年代际变化趋势

按照Bradley等[2]和我国气候蓝皮书(1990)的研究，我国气温变化总的趋势与北半球的变化相一致。本世纪最冷的时期是1900—1920年，从20年代到40年代，气温升高，到40年代气温达到最高，从40年代以后到70年代中期，北半球又变冷，而从70年代中气

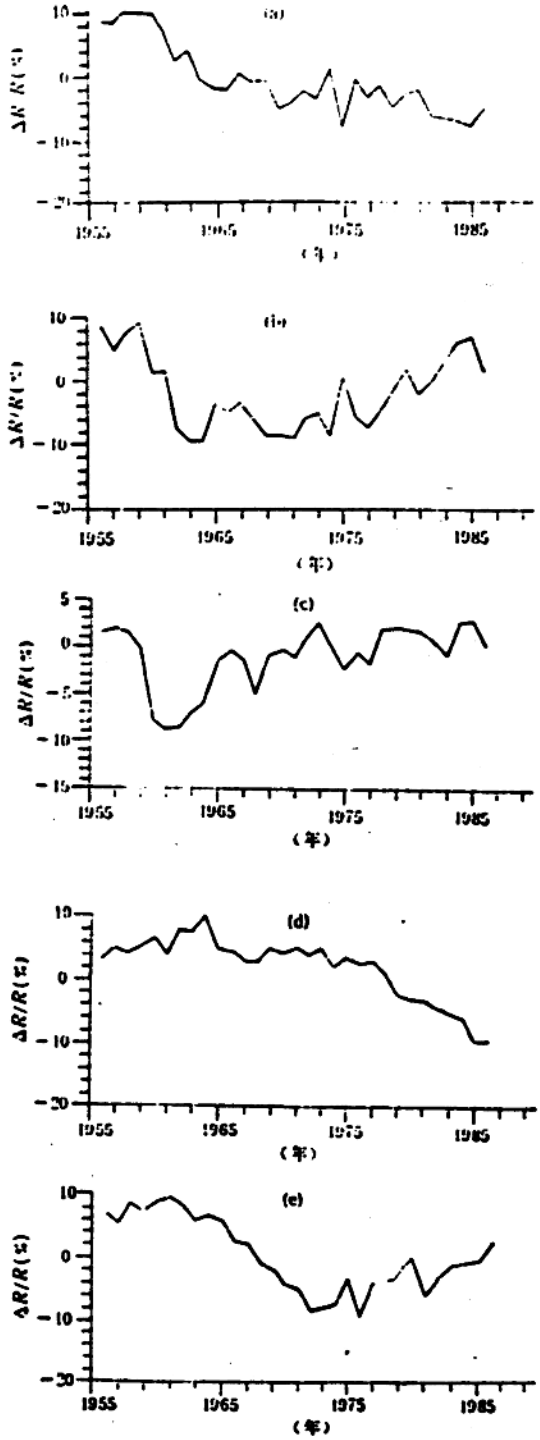

图2　我国各区域夏季6—8月降水距平百分率ΔR/R的十年滑动平均

(a) 黄河流域和华北地区；(b) 江淮流域；(c) 长江中下游流域；(d) 华南地区；(e) 东北地区