Agriculture and sunspots

Researchers at the Appleton Laboratory, in England, say that the present low level of world food reserves may be associated with the decline in solar activity during the approach to the 1974–75 sunspot minimum. Presumably because of their effects on temperature and rainfall, the 11-year and 22-year sunspot cycles appear to influence agricultural productivity in certain parts of the world. Modulations of 10% to 50% of the wheat production in China, the United States and the Soviet Union seem to be correlated with the solar cycles, suggest J. W. King, E. Hurst, A. J. Slater, P. A. Smith and B. Tamkin. The forthcoming World Food Conference in Rome might well wish to discuss implications for global agricultural planning.

WORLD food reserves have, until recently, been larger than the variability in production associated with the weather, and oscillations about the general upward trend of agricultural productivity could be ignored. It is now apparent, however, that urgent consideration has to be given to the impact of climatic changes on food production. The world's grain reserves have dwindled from the 1969 peak (19% of annual consumption) to only 7% of annual consumption, less than the variability of about 10% induced by the weather. Although many people have reported associations between the solar cycle and the weather, relatively little attention has been paid to the fact that the 11-year and the 22-year sunspot cycles could produce important modulations of agricultural productivity.

The world wheat production figures for 1949–73 can be used to show how the sunspot cycles appear to influence food production. Sunspot maxima occurred at the end of 1957 and again in 1968 and it seems significant that global wheat production in 1958 was greater than in each of the next five years, whereas that in 1968 was greater than the average of the next four years. In 1954 (a year of sunspot minimum) production was less than in any of the two preceding or the two following years. In North and Central America, for example, the crop in 1954 was smaller than any other year for which we have data; the average crop during the five previous years was 25% bigger than that of 1954.

The fact that wheat production in the Northern Hemisphere increases at around sunspot maximum can be deduced from the wheat figures for many countries. In the People's Republic of China, the annual production during 1956–58 (centred on the 1957 sunspot maximum) was 22% greater than during the period 1960–65; the total produced in 1958 has not been equalled in any year up to and including 1973. The average production in the Soviet Union during 1956–58 was, as in China, greater than during 1960–65; in 1958 the crop was 54% bigger than in 1963. The average wheat production in Canada during 1967–69 (centred on the 1968 sunspot maximum) was 27% greater than that during the four subsequent years, 1970–73; production in both 1968 and 1969 was higher than in any of the four years 1970–73.

Over much of the Northern Hemisphere, therefore, wheat production appears to be significantly enhanced near sunspot maximum and reduced at sunspot minimum. In parts of the Southern Hemisphere, however, the opposite is observed. In Argentina, for example, the three years when most wheat was produced were 1954, 1964 (the two sunspot minimum years) and 1963; the average crop for these three years was 50% greater than for the nine years 1965–73. The African wheat crop in 1954 was bigger than in any of the next eight years; it was thus, as in Argentina, bigger than in any year until 1963. In Australia the 1957 (sunspot maximum) crop was smaller than in any of the previous eight years; in these eight years an average of 83% more wheat was produced than in 1957.

The facts show that the modulation of wheat production associated with the 11-year sunspot cycle seems to be at least 10% in many parts of the word; in certain countries it may even be greater than 50%. A consequence of this modulation may be the fact that the Soviet wheat crop in 1972 was smaller than that of 1971 which was, in turn, less than that of 1970. It is well known that the 'failure' of the 1972 crop led to massive purchases of wheat from the United States and it may reasonably be suggested, in view of the reduced Soviet crops in the years following the 1957–58 solar maximum, that this failure was associated with the decline of solar activity between the 1968 sunspot maximum and the minimum due in about 1974.

Figure 1 shows that the yield per acre of two crops in Britain appeared to be negatively correlated with sunspot number during two complete solar cycles between 1937 and 1957. The cycles seem to have been accompanied by a 10% modulation of the yield per acre but it should be stressed that the relationship between agricultural productivity and the sunspot cycle is not always as clear as Fig. 1 would suggest; some reasons for this are discussed later.

It is not appropriate to describe here the complicated relationships that exist between the solar cycle and the weather in different parts of the world, but some examples of the association between sunspot number, temperature and rainfall are worth mentioning. Figure 2 shows how the rainfall at Fortaleza in Brazil varied during the 'double' or 22-year sunspot cycle; data are plotted for the period 1865–1925 which covered almost three double solar cycles. The rainfall followed the double sunspot cycles closely and the modulation associated with the double cycle amounted to about 35% of the average annual total. P. D. Tyson, as reported in the *Johannesburg Star* in April this year, observed that the rainfall in parts of South Africa exhibits a pronounced modulation (approximately 25% of average annual total) with a period of about 20 years. We have noticed that this oscillation closely resembles the double sunspot cycle and also that the shorter-period oscillation which Tyson observed in the rainfall over the most southerly part of Africa is in antiphase with the 11-year sunspot cycle.

The rainfall in parts of North America is also strongly influenced by the double sunspot cycle. W. O. Roberts[1] has pointed out that droughts in certain regions of the United States that are important for agricultural purposes occur in the years around every second sunspot minimum. The last drought was centred on the sunspot minimum year 1954 and we believe it is significant that the wheat crop in the United States in that year was 12% smaller than the average for the five previous years. It is also significant that in 1974, when the next drought was to be expected, lack of rain has adversely affected the maize crop in the United States. The wheat figures for 1949–73 suggest that Australian wheat production is also influenced by the double sunspot cycle.

Figure 3 shows how the July temperature in central England varied during the 130 years from 1750–1880; evidently a modulation of about 0.75° C occurred in phase with the double sunspot cycle except for a short period around 1850 when the phase of the temperature variation jumped by half an 11-year cycle. More recently, the growing

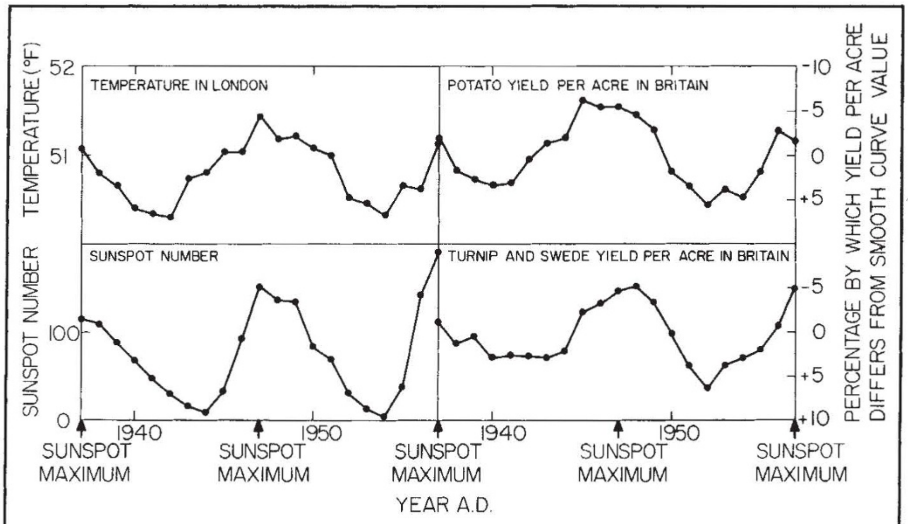
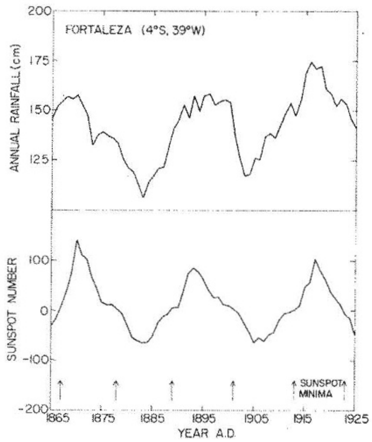
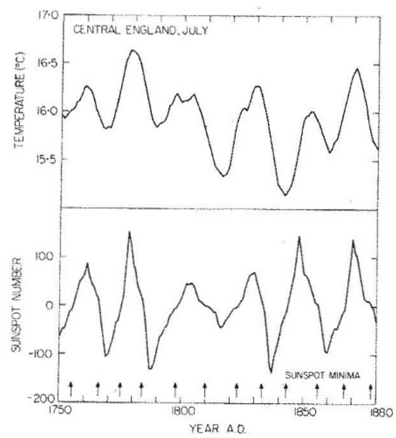


FIGURE 1 *(above) shows variations during two complete sunspot cycles. Top left: 5-point mean of mean annual temperatures at Kew, London. Bottom left: Yearly mean sunspot numbers. Right: Percentage differences between 5-point mean of yearly agricultural yields and the trend obtained by drawing a smooth curve through the 5-point means.* FIGURE 2 *(below left): Top: 13-year mean of annual rainfall at Fortaleza, Brazil. Bottom: Yearly mean sunspot numbers, plotted with "even" 11-year cycles inverted in the usual representation of the "double" or 22-year sunspot cycle.* FIGURE 3 *(below right): Top: Smoothed mean of the central England July temperatures. Bottom: Yearly mean sunspot numbers, plotted with the even 11-year cycles inverted.*





season (a measure of temperature) in Scotland has undergone a 10% fluctuation in phase with the 11-year sunspot cycle. The rainfall in England also appears, during the past 80 years at least, to have been influenced by the 11-year cycle. Data from Kew (1891–1930) and Bedford (1931–70) show that the rainfall there underwent a modulation in phase with the 11-year cycle. Averages for periods of four years around the sunspot maxima and four years around the sunspot minima (the extreme year of the solar cycle being the third of the four years in every case) show that at Kew the average rainfall at sunspot maximum (four sunspot maxima, 16 years) was 17% greater than at sunspot minimum (three sunspot minima, 12 years). At Bedford the rainfall at sunspot maximum (16 years) was 16% greater than at sunspot minimum (16 years). It does not seem unreasonable to suggest, since the 11-year sunspot cycle appears to modulate both the rainfall and the temperature over Britain, that agricultural productivity may be affected by the solar cycle.

The temperature data shown in Fig. 3 provide evidence of a long-period variation which will be described elsewhere, but it should be pointed out here that the phases of the two long-period temperature variations (78 years and 181 years) observed in parts of the Northern Hemisphere are such that the maximum temperatures associated with these variations occurred in 1934 and 1922 respectively; the period around 1930 was thus relatively warm. It is well known that the period around 1700 was relatively cold; it is referred to as the "Little Ice Age". Temperature data published by Manley[2] for central England can be used to show that the average length of the growing season during the decade 1691–1700 was about 220 days. Temperatures from Kew for the particularly favourable decade 1931–40 show that the average length of the growing season was approximately 280 days and it is evident (without allowing for the slight temperature difference which exists between central England and Kew) that long-term temperature trends are sufficient to cause the growing season in England to vary by about 60 days, approximately 25%. A return to the conditions which existed around 1700 would obviously result, from an agricultural point of view, in a much less favourable environment than that which has existed during the twentieth century. It is worthy of note that a downward trend (based on farmers' estimates compiled each year for six different crops, and published in *The Times*, September 2 this year) appears to have occurred recently in British agricultural productivity. The average estimate (with 100% indicating 'full growth') for the years 1964–68 was 94.23%, whereas for the years 1969–74 it was only 91.86%. These figures indicate a decline of 4.6% per decade and, although evidence such as this cannot be used to establish the exact connection between agricultural productivity and long-term climatic trends, it does suggest that the gradual return to colder drier weather which has taken place recently may be having an adverse effect on agricultural output in Britain.

The physical processes through which solar radiation changes associated with the 11-year and 22-year sunspot cycles affect the weather have not yet been identified. At present there is not even a general picture, much less an explanation, of how the climatic effects associated with the solar cycles vary over the Earth. It is already known, however, that the 11-year cycle and the rainfall are positively correlated at some latitudes and negatively correlated at others; such information could be important for agricultural planning purposes. It is also known that the phase difference between the solar cycle and the rainfall variation at particular locations undergoes sudden jumps of up to 180° but the pattern, if any, of such changes is not known.

Much more work needs to be done to establish the spatial morphology of the various climatic effects associated with the sunspot cycles. It seems reasonable, however, to expect that during the next decade man's knowledge of the effects of the 11-year and 22-year cycles on the weather may advance sufficiently for some of these to be taken into account in global agricultural planning.

We thank Mr E. H. Locke and Professor P. D. Tyson for supplying data.

1 Roberts, W. O., *Proc. Symp. on possible relationships between solar activity and meteorological phenomena* (NASA, 1974).
2 Manley, G., *Q. Jl. R. Met. Soc.*, **100**, 389 (1974).