# SPECTRAL ANALYSIS OF COFFEE, MAIZE AND WHEAT PRODUCTION IN KENYA.

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Abstract

Spectral methods are applied to coffee, maize, and wheat production series. Coffee and wheat spectra reveal two cycles each. For coffee, most spectral power is concentrated at a frequency corresponding to a 2.4 - year cycle. A second coffee cycle has a period of about 4.6 years. Similarly, wheat has 5-year and 2.9 year cycles. Maize has one cycle lasting for a period of 2.8 years.

## Spectral Analysis of Coffee, Maize and Wheat Production in Kenya

### 1. Introduction

A study of rainfall variation in Kenya has shown that most rainfall series, as recorded at various rainfall stations, possess cycles with periods ranging from 2½ to 3½ years.[1] Since most crops depend on rainfall one would suspect the existence of periodicities in crop production.

Cyclical movements in crop production are unfavourable since they are associated with periodic food shortages. Further, for an agricultural country variability in crop production may mean lack of stability in the production of its export commodities resulting in the inability of the country to keep its balance of payments deficitly within reasonable limits.

It is the aim of this paper to investigate the existence of periodicities in the production of selected major crops in Kenya and to compare the lengths of some of the crop cycles with the rainfall cycles susing spectral methods. The selected crops are coffee, maize and wheat.

### 2. Spectral Mwthods

Spectral analysis of time series employs statistical method which describe time series data in the frequency domain (rather than in the time domain) by the Fourier transform of the autocorrelation function.[2] The estimate of the normalized power spectrum, averaged over a frequency band centred at $w_j$, is

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1. See authors' "Is there rainfall cycle?", The Weekly Review, March 14, 1975 (nairobi).

2. For more detail, see I.D.S. Working Papers 133, (1973) and 211(1975)(University of Nairobi) by author.

(2.1) $$f_{xx}(w_j) = \frac{1}{2\pi} + \frac{1}{\pi}\sum_{\tau=1}^{M} R_{xx}(\tau)\,\lambda(\tau)\,\cos\omega_j\tau$$

where $M$ = truncation point,

$\lambda(\tau)$ - lag window

$w_j = \frac{\pi j}{M}$,

$R_{xx}(\tau)$ = autocorrelation function,

$\tau$ = lag.

The autocorrelation function is usually obtained by first computing the covariance function given by

(2.2) $C_{xx}(\tau) = \frac{1}{n}\sum_{t=1}^{n-\tau}(X_t-\bar{X})\,(X_{t+\tau}-\bar{X})$ and then divide (2.2) at different lags by $C_{xx}(0)$.

(2.3) $\bar{X} = \frac{1}{n}\sum_{t=1}^{n-\tau} X_t$ is the mean of the time series recorded at equidistant time points t.

Spectral methods usually assume that the data is stationary both in the mean and variance. Economic and some meteorological time series are usually not stationary. Some measure of stationarity is achieved by detrending the data. The method of detrending the present data is that of first differences.

In addition, these methods normally require long series if good results are to be expected. The series used is not long enough but it is hoped the results are satisfactory.

## 3. The Data

Annual coffee production recorded, in tons, from 1927 to 1974, annual maize production, in bags, from 1919 to 1972 and annual wheat production, also recorded in bags, from 1922-1972 were used in the analysis. These data are given in table 1.

The corresponding diagrams for the crops are given in Figure 1 and show both a strong trend and wide variability about the trend.

For the purpose of comparing rainfall and maize spectra, rainfall data for important maize growing areas are given in table 2.

TABLE 1

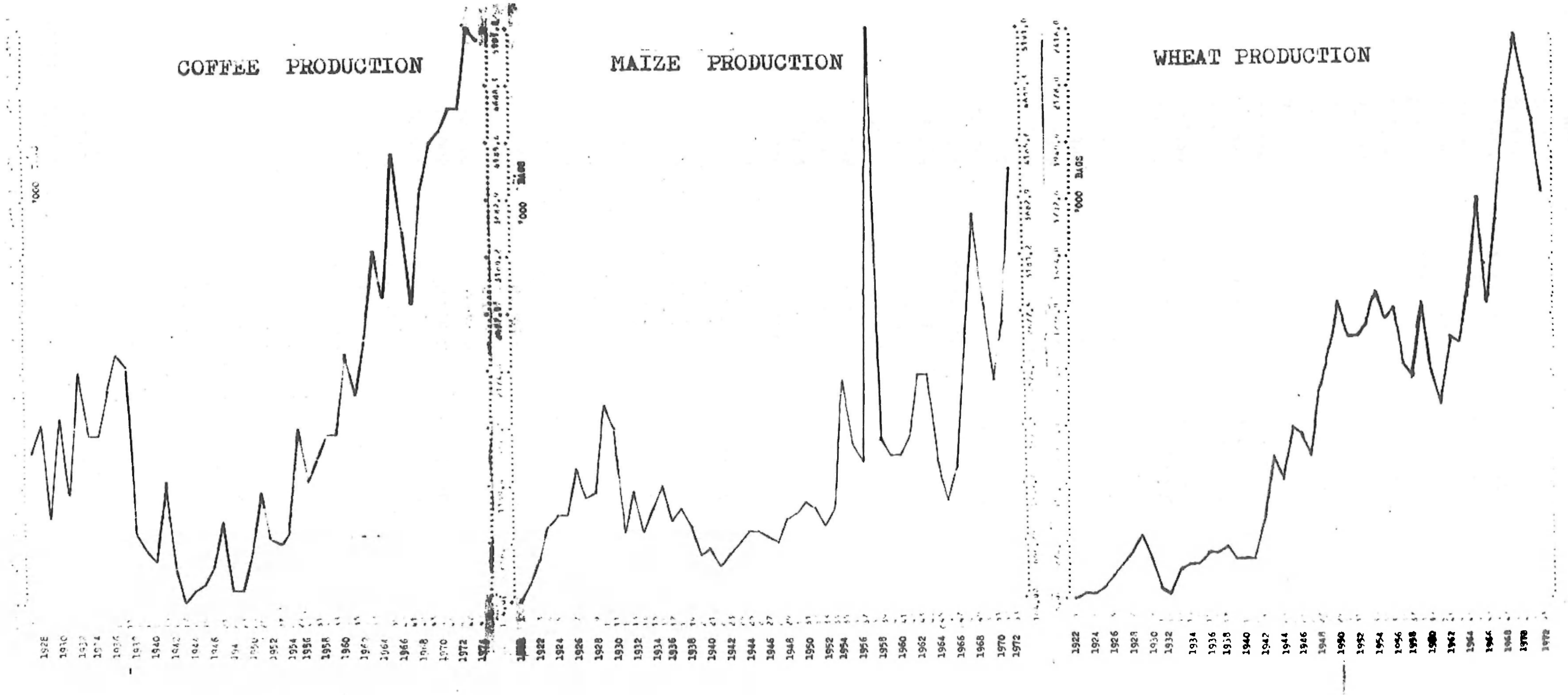
ANNUAL PRODUCTION OF SELECTED CROPS

| YEAR | COFFEE (Tons) | MAIZE+ (Bags) | WHEAT (Bags) |
|---|---|---|---|
| 1919 | | 317,525 | |
| 1920 | | 164,722 | |
| 1921 | | 338,837 | |
| 1922 | | 517,877 | 35,793 |
| 1923 | | 833,640 | 55,920 |
| 1924 | | 893,108 | 61,067 |
| 1925 | | 926,614 | 80,069 |
| 1926 | | 1,314,643 | 120,569 |
| 1927 | 21,300 | 1,088,706 | 173,958 |
| 1928 | 24,629 | 1,099,317 | 228,141 |
| 1929 | 14,588 | 1,858,586 | 293,468 |
| 1930 | 25,092 | 1,649,728 | 194,337 |
| 1931 | 17,009 | 762,622 | 86,362 |
| 1932 | 30,400 | 1,139,616 | 63,498 |
| 1933 | 23,501 | 746,893 | 145,581 |
| 1934 | 23,440 | 969,486 | 180,205 |
| 1935 | 28,659 | 1,150,125 | 171,571 |
| 1936 | 32,367 | 863,398 | 222,000 |
| 1937 | 30,840 | 968,076 | 234,016 |
| 1938 | 12,400 | 908,320 | 274,400 |
| 1939 | 10,900 | 618,240 | 224,000++ |
| 1940 | 9,700 | 672,000++ | 224,000++ |
| 1941 | 18,500 | 504,000++ | 239,680 |
| 1942 | 8,900 | 623,840 | 418,880 |
| 1943 | 4,994 | 730,240 | 712,320 |
| 1944 | 6,200 | 847,840 | 604,800 |
| 1945 | 6,952 | 859,050 | 851,200 |
| 1946 | 9,043 | 789,600 | 817,600 |
| 1947 | 14,075 | 719,040 | 696,640 |
| 1948 | 6,562 | 945,280 | 1,014,720 |
| 1949 | 6,335 | 1,034,880 | 1,207,360 |
| 1950 | 9,938 | 1,121,120 | 1,421,280 |
| 1951 | 16,922 | 1,109,920 | 1,253,280 |
| 1952 | 12,190 | 928,480 | 1,268,960 |
| 1953 | 11,350 | 1,103,200 | 1,330,560 |
| 1954 | 12,335 | 2,299,360 | 1,485,120 |
| 1955 | 23,919 | 1,731,520 | 1,354,080 |
| 1956 | 18,350 | 1,534,400 | 1,401,120 |
| 1957 | 20,837 | 5,813,920 | 1,143,520 |
| 1958 | 23,355 | 1,749,440 | 1,077,440 |
| 1959 | 23,394 | 1,610,560 | 1,426,880 |
| 1960 | 32,220 | 1,564,640 | 1,116,640 |
| 1961 | 27,677 | 1,755,040 | 941,920 |
| 1962 | 33,657 | 2,369,920 | 1,262,240 |
| 1963 | 43,496 | 2,356,480 | 1,236,480 |
| 1964 | 38,753 | 1,525,440 | 1,508,640 |
| 1965 | 54,715 | 1,162,560 | 1,928,640 |
| 1966 | 46,128 | 1,504,160 | 1,438,080 |
| 1967 | 38,056 | 2,786,560 | 1,816,640 |
| 1968 | 50,356 | 3,949,120 | 2,422,650 |
| 1969 | 56,026 | 3,139,360 | 2,705,920 |
| 1970 | 57,180 | 2,303,840 | 2,480,800 |
| 1971 | 59,582 | 2,873,920 | 2,303,840 |
| 1972 | 59,628 | 4,400,480 | 1,955,520 |
| 1973 | 68,414 | | |
| 1974 | 67,366 | | |

+ 1 bag = 200 lbs. 1 ton = 20 cwt = 2240 lbs = 11.2 bags.
++ estimates.

Source: Ministry of Agriculture Annual Report & Statistical Abstract, Republic of Kenya.

Figure 1



## TABLE 2

## RAINFALL DATA FOR STATIONS IN MAJOR CROP GROWING AREAS (millimetres)

| YEAR | KABETE | KIAMBU | KITALE | KISUMU | MURANGA | NAKURU | NAROK | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| 1901 | | | | | 1144 | | | |
| 1902 | | | | | 1202 | | | |
| 1903 | | | | 1313 | 1319 | | | |
| 1904 | | | | 1090 | 1230 | 663 | | |
| 1905 | | | | 1353 | 1222 | 929 | | |
| 1906 | | | | 1810 | 1139 | 783 | | |
| 1907 | | | | 773 | 1313 | 1006 | | |
| 1908 | | 968 | | 1337 | 1023 | 973 | | |
| 1909 | | 915 | | 860 | 1269 | 859 | | |
| 1910 | 705 | 672 | | 831 | 1007 | 691 | | |
| 1911 | 1100 | 1101 | | 924 | 1221 | 727 | | |
| 1912 | 1440 | 1481 | | 1176 | 1539 | 1040 | | |
| 1913 | 900 | 889 | | 1096 | 1126 | 890 | | |
| 1914 | 1125 | 1134 | 1366 | 1241 | 1239 | 970 | 747 | 1117 |
| 1915 | 1050 | 1054 | 1337 | 1191 | 1310 | 904 | 956 | 1115 |
| 1916 | 1171 | 1137 | 1421 | 1430 | 1352 | 1135 | 823 | 1210 |
| 1917 | 1455 | 1401 | 2080 | 1779 | 1503 | 1733 | 1114 | 1581 |
| 1918 | 652 | 779 | 652 | 825 | 913 | 913 | 351 | 685 |
| 1919 | 841 | 1188 | 1079 | 1186 | 986 | 1039 | 861 | 1026 |
| 1920 | 1279 | 1197 | 1440 | 1056 | 1187 | 979 | 851 | 1141 |
| 1921 | 651 | 637 | 771 | 1042 | 707 | 651 | 473 | 705 |
| 1922 | 1342 | 1234 | 1157 | 1165 | 1130 | 881 | 688 | 1085 |
| 1923 | 1518 | 1551 | 1472 | 1430 | 1313 | 1137 | 870 | 1327 |
| 1924 | 712 | 638 | 1409 | 924 | 699 | 738 | 466 | 798 |
| 1925 | 812 | 855 | 1234 | 1178 | 853 | 672 | 920 | 932 |
| 1926 | 973 | 969 | 1621 | 1257 | 1328 | 920 | 719 | 1112 |
| 1927 | 830 | 816 | 659 | 820 | 747 | 650 | 549 | 724 |
| 1928 | 893 | 826 | 876 | 1102 | 1056 | 738 | 932 | 860 |
| 1929 | 1093 | 1138 | 1255 | 876 | 1152 | 717 | 528 | 966 |
| 1930 | 1525 | 1658 | 1548 | 1239 | 1473 | 1292 | 1211 | 1421 |
| 1931 | 1196 | 1239 | 1355 | 975 | 1344 | 867 | 701 | 1097 |
| 1932 | 1155 | 1047 | 1384 | 1330 | 1436 | 989 | 730 | 1193 |
| 1933 | 655 | 816 | 1036 | 1066 | 885 | 666 | 300 | 779 |
| 1934 | 648 | 630 | 1124 | 957 | 970 | 569 | 381 | 754 |
| 1935 | 868 | 1190 | 1279 | 1218 | 1076 | 684 | 840 | 994 |
| 1936 | 1035 | 965 | 1439 | 1198 | 1169 | 938 | 784 | 1064 |
| 1937 | 1486 | 1661 | 1539 | 1339 | 1784 | 949 | 931 | 1249 |
| 1938 | 784 | 851 | 1227 | 1554 | 1008 | 824 | 384 | 947 |
| 1939 | 603 | 556 | 1220* | 879 | 653 | 610 | 574 | 728 |
| 1940 | 1065 | 1203 | 1368 | 1310 | 1221 | 869 | 781 | 1116 |
| 1941 | 1185 | 1212 | 1484 | 1336 | 1273 | 959 | 697 | 1164 |
| 1942 | 1135 | 921 | 1235 | 1017 | 1253 | 840 | 837 | 1034 |
| 1943 | 593 | 679 | 1030 | 936 | 1250 | 750 | 431 | 806 |
| 1944 | 699 | 780 | 1246 | 1228 | 703 | 659 | 693 | 892 |
| 1945 | 846 | 965 | 1274 | 862 | 892 | 929 | 814 | 912 |
| 1946 | 891 | 946 | 1459 | 1421 | 1197 | 663 | 497 | 1005 |
| 1947 | 1316 | 1467 | 1412 | 1100 | 1400 | 1087 | 993 | 1254 |
| 1948 | 949 | 869 | 1416 | 872 | 1201 | 907 | 901 | 959 |
| 1949 | 625 | 615 | 1218 | 951 | 769 | 752 | 489 | 774 |
| 1950 | 748 | 885 | 1245* | 763 | 1302 | 757 | 797 | 922 |
| 1951 | 1439 | 1630 | 1631 | 1562 | 1761 | 1098 | 1119 | 1483 |
| 1952 | 839 | 883 | 1186 | 1125 | 957 | 788 | 651 | 918 |
| 1953 | 759 | 661 | 985 | 974 | 1300 | 699 | 397 | 825 |
| 1954 | 974 | 826 | 1081 | 980 | 1329 | 1088 | 804 | 1012 |
| 1955 | 909 | 959 | 1196 | 850 | 877 | 940 | 794 | 933 |
| 1956 | 942 | 845 | 1219* | 1007 | 1345 | 967 | 894 | 1031 |
| 1957 | 1365 | 1479 | 1324 | 943 | 1340 | 741 | 1079 | 1182 |
| 1958 | 973 | 1353 | 1146 | 915 | 1498 | 1055 | 993 | 1128 |
| 1959 | 901 | 939 | 960 | 710 | 1063 | 718 | 714 | 861 |
| 1960 | 865 | 966 | 1341 | 963 | 938 | 760 | 808 | 948 |
| 1961 | 1664 | 1694 | 1697 | 1497 | 1885 | 1411 | 1032 | 1554 |
| 1962 | 1209 | 1062 | 1510 | 1517 | 1239 | 919 | 1097 | 1221 |
| 1963 | 1715 | 1768 | 1469 | 1274 | 1998 | 1050 | 1399 | 1519 |
| 1964 | 1125 | 915 | 1240 | 1172 | 1061 | 947 | 798 | 1037 |
| 1965 | 982 | 781 | 945 | 875 | 1028 | 471 | 569 | 807 |
| 1966 | 1118 | 989 | 1329 | 1157 | 1026 | 768 | 798 | 1021 |
| 1967 | 1271 | 1285 | 1518 | 1011 | 1601 | 662 | 669 | 1148 |
| 1968 | 1330 | 1253 | 1234 | 1269 | 1812 | 762 | 883 | 1223 |
| 1969 | 651 | 575 | 1221 | 1005 | 910 | 654 | 643 | 808 |
| 1970 | 1112 | 973 | 1489 | 1001 | 1159 | 1056 | 1042 | 1119 |
| 1971 | 963 | 1192 | 1293 | 698 | 965 | 888 | 687 | 992 |
| 1972 | 922 | 890 | 1298 | 1489 | 1389 | 845 | 879 | 1101 |
| 1973 | 772 | 620 | 1374 | | 720 | 727 | 835 | |

* estimates

Source: East African Meteorological Department, Nairobi.

The spectra of the three crops are shown in Figure 2. The coffee spectrum shows that most of the variance of the series is concentrated at high frequencies. This is due to the tendency of coffee production having rapid oscillations. Most of the spectral power is found at frequencies in the neighbourhood of 4.2 cycles per decade with a peak corresponding to a 2.4-year cycle. There is a second cycle lasting for an average period of 4.6 years. The peak at zero frequency is due to the (increasing) trend in coffee production over the years.

The two coffee cycles are closer to true cycles if we base our judgement on the fact that the 2.4-year cycle is close to the first harmonic of the 4.6-year cycle. The actual first harmonic being the one corresponding to a 2.3-year cycle.

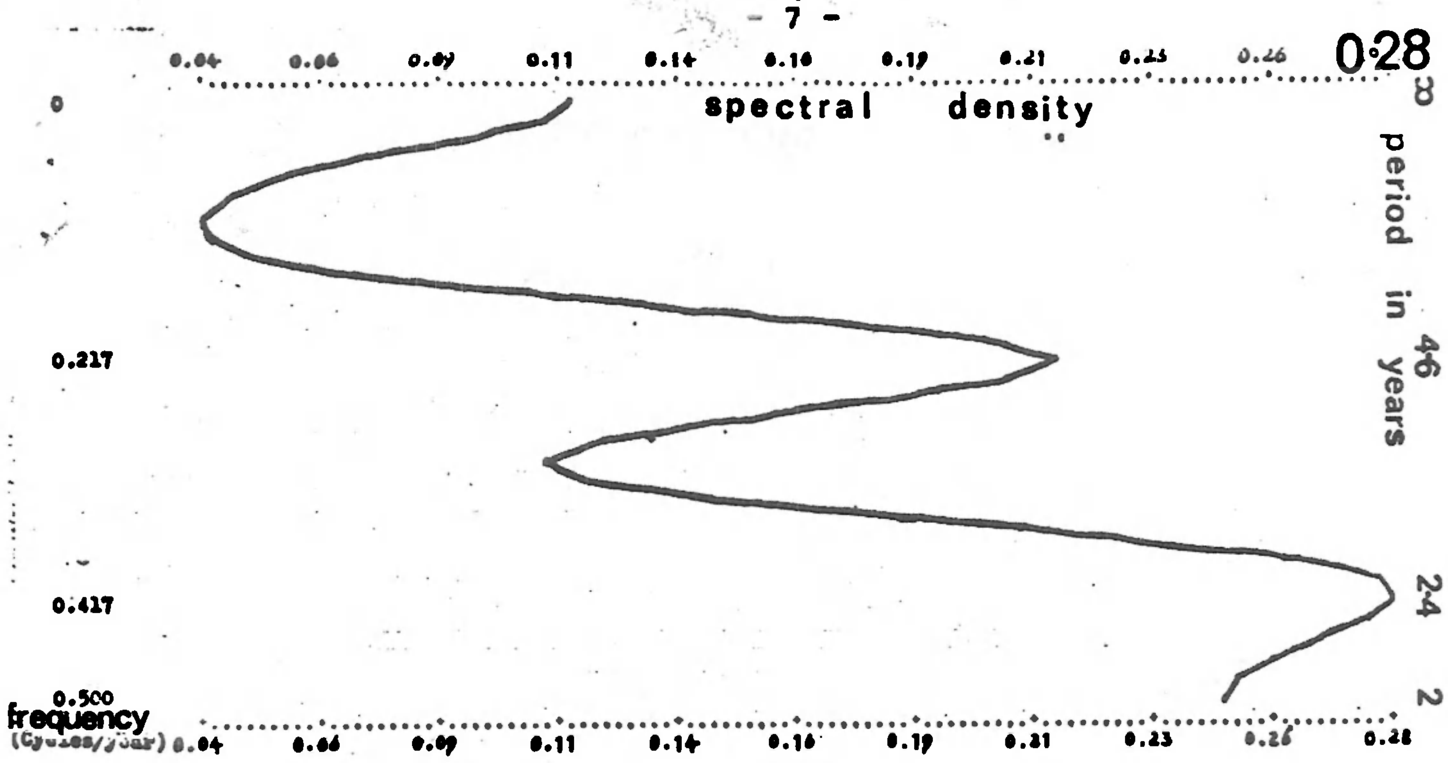
The maize series possesses a peak at 3.6 cycles per decade with a cycle of an average length of 2.8 years. There may be a possibility of a 5-year cycle.

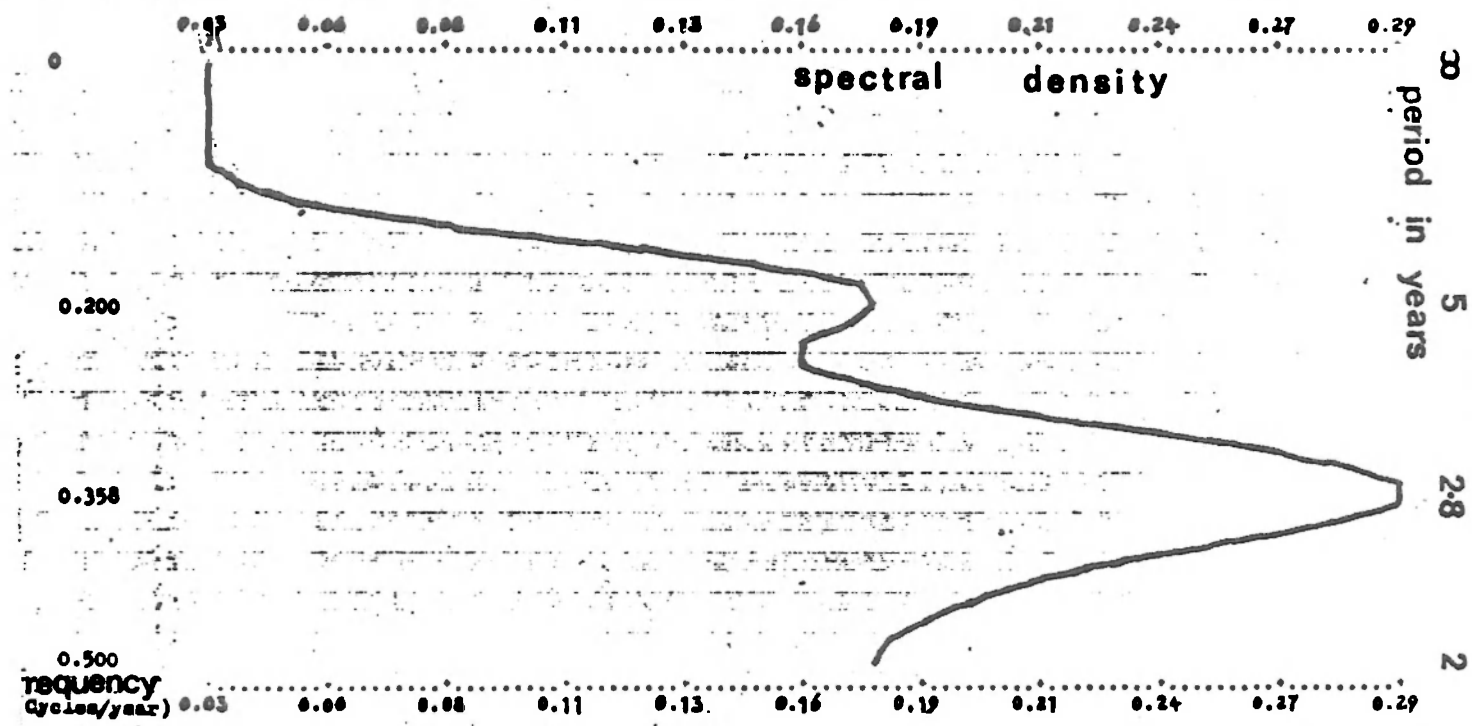
The wheat spectrum reveals two important peaks. These correspond to the 2.9-year and 5-year cycles. Except for stronger spectral power at the frequency band corresponding to the 5-year cycle, the wheat spectrum is similar to the maize spectrum. This may be due the similarities in rainfall variation in the maize and wheat growing areas. The prominence of the 5-year wheat cycle may be due to the difference in rainfall variability in the areas where the two crops are not grown together.

Using frequencies per decade and the existence of peaks at those frequency bands, it is clear that there are approximately 4.2 coffee "bumper harvests" and 2.2 "moderate harvests" every ten years. These together give 6.4 "good harvests" and 3.6 "bad harvests" every decade.

There are 3.6 "bumper harvests" for the maize crop every ten years with a little chance of 2 "moderate harvests". The uncertainty about the existence of the"moderate harvest" makes it possible for the people of Kenya to be faced with 6.4 food shortages every decade.

Because of the importance of the peak corresponding 2 cycles per decade, wheat has 5.4 "good harvests" every ten years, 3.4 of which are "bumper harvests".


spectral density
period in years
frequency
(Cycles/year)
0.04
0.06
0.09
0.11
0.14
0.16
0.19
0.21
0.23
0.26
0.28
0
0.217
0.417
0.500
∞
4·6
2·4
2


spectral density
period in years
frequency
(Cycles/year)
0.03
0.06
0.08
0.11
0.13
0.16
0.19
0.21
0.24
0.27
0.29
0
0.200
0.358
0.500
∞
5
2·8
2

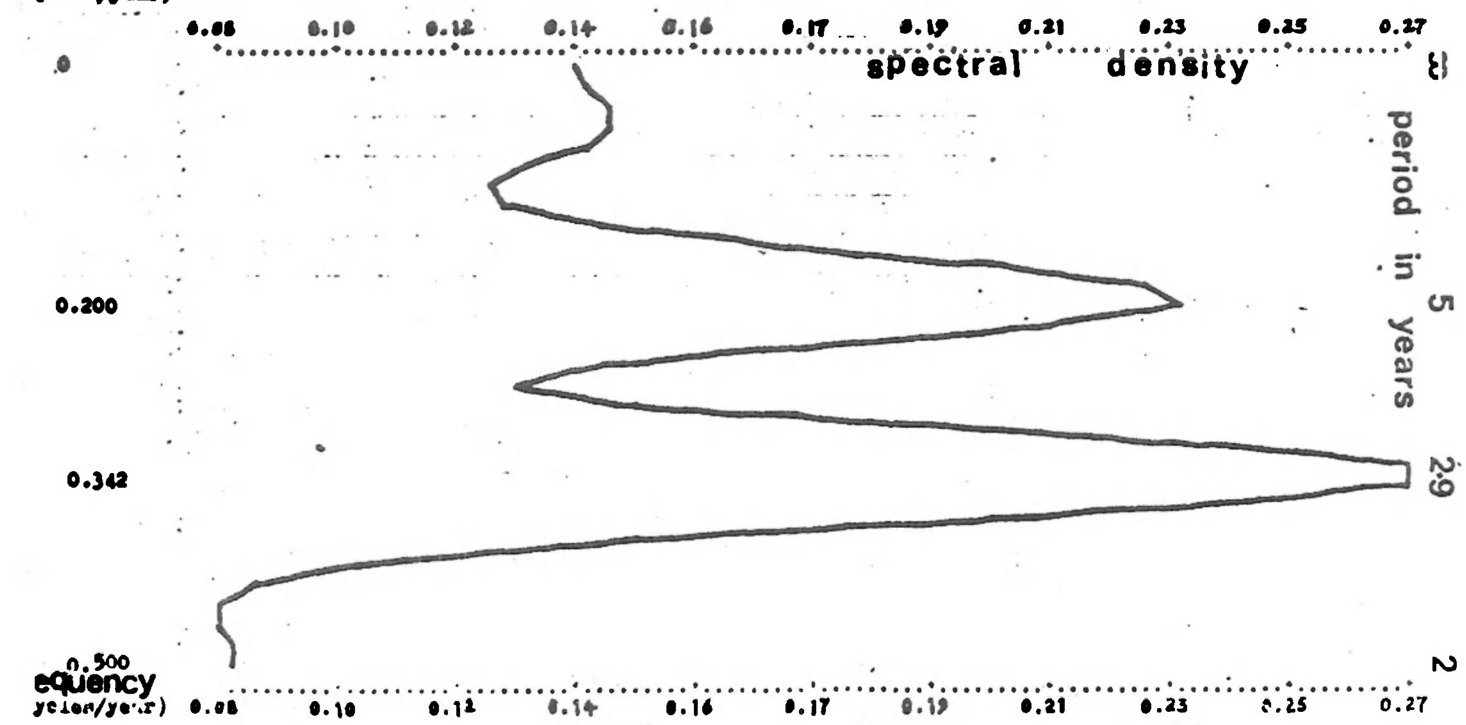
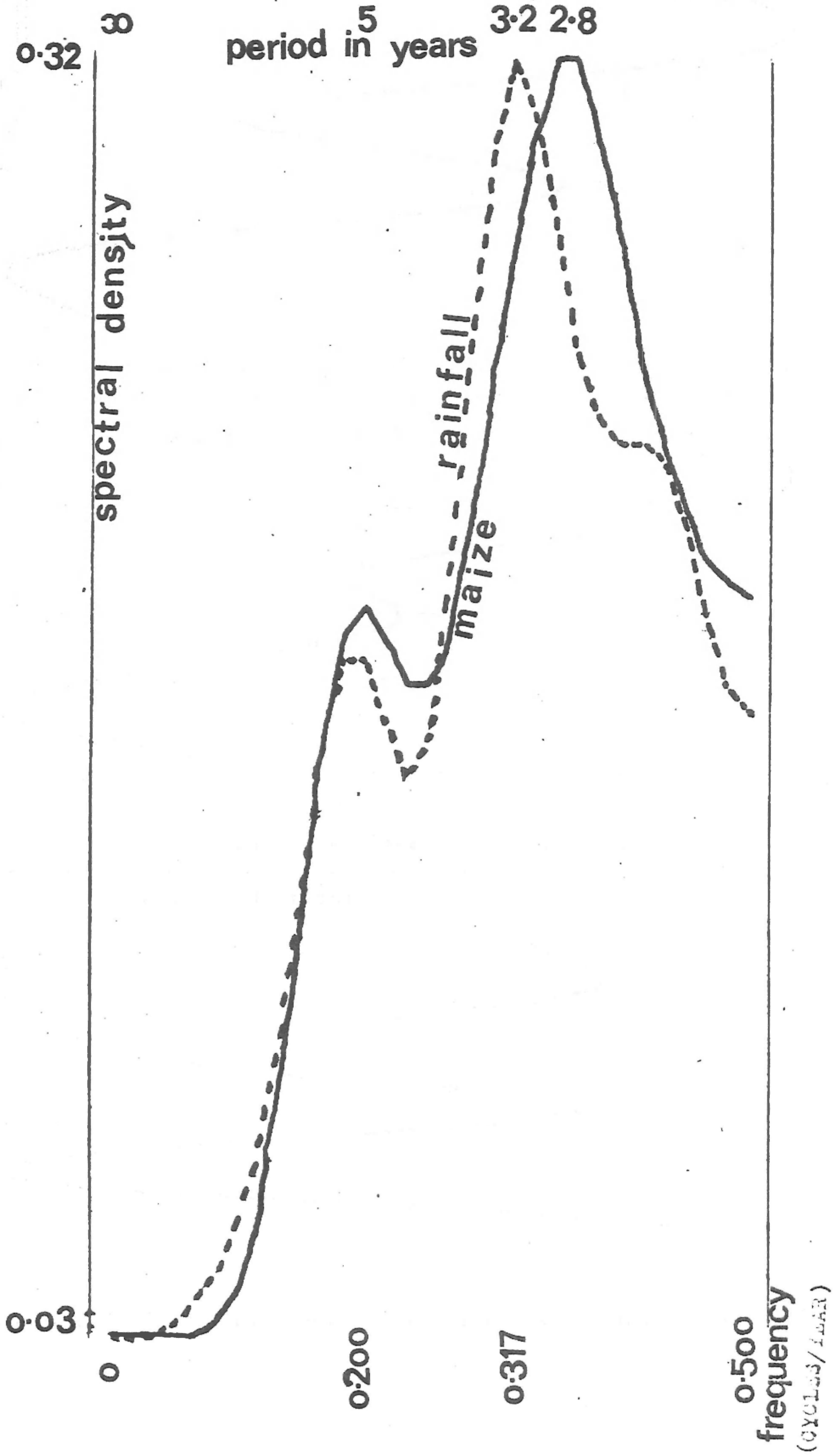

spectral density
period in years
frequency
(Cycles/year)
0.08
0.10
0.12
0.14
0.16
0.17
0.19
0.21
0.23
0.25
0.27
0
0.200
0.342
0.500
∞
5
2·9
2

Figure 3

MAIZE AND RAINFALL SPECTRA



The short coffee cycle may be ascribed to to short rainfall cycles in the coffee growing areas. The average length of the rainfall series in these areas was found to be 2.5 years(see Masaya,(1975)).

Cycles of shorter periods in the maize and wheat series are close to the period of 3.2 years for the average rainfall series of table 2. The rainfall stations mentioned in the table are considered in this investigation to be the important maize growing areas. The maize and average rainfall spectra, as shown in Figure 3, are very similar.

## 5. Conclusion

The investigation of the coffee, maize and wheat series have revealed a 5-year cycle in both coffee and wheat production series. The two series have two additional cycle whose lengths are 2.4 and 2.9 years respectively. The intensity of spectral power associated with these cycles is greater than that associated with the two 5-year cycles.

Maize has one dominant 2.8-year cycly. There is, however, an uncertain 5-year cycle.

Of the three crops studied, coffee is the most reliable with less than 4 crop shortages every ten years. Wheat is second with a little more than 4.5 shortages. Maize is the most unreliable of the three crops. Maize shortages may occur more than 6 times every ten years. The possibility of a 5-year cycle may, however, reduce the number of maize shortages to about 4.5 times every decade. Considering that maize is an important staple food in the country 4.5 shortages every ten years constitute every serious problem.

Variability in crop production can be mimised by taking the following measures, individually or collectively:

1. Irrigation schemes
2. Building granaries to take care of possible waste which usually follows "bumper harvests". The stored grain could then be used during drought years.
3. In the case of maize, importing an amount of maize every year to be stored in granaries to counter-act possible shortages.
4. Make massive use of land during years of heavy rains.

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