SOME ASPECTS OF CLIMATIC VARIABILITY.

WITH SPECIAL REFERENCE TO RAINFALL IN NEW SOUTH WALES.

By

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This Department recently received a terse inquiry from a correspondent asking whether rainfall in New South Wales is declining and requesting data indicating average precipitation over periods of ten years. The question whether rainfall is declining, increasing or shows no variation is more than an academic one in a country such as Australia, where average precipitation over large areas is all too low and where agricultural and pastoral activities measure large in its economy. It should be of particular interest to those concerned with future policy not only of agriculture but of such kindred national undertakings as water and soil conservation and afforestation. But the subject is of considerable general interest, and the following is an examination of rainfall variability insofar as the comparatively meagre data available will allow.

Extreme Variability of N.S.W. Rainfall.

In determining the climate of any particular area or district the basis is generally the average experience in regard to the various factors. In New South Wales, however, these factors, rainfall in particular, are extremely variable. We speak of normals, means or averages, but these are usually mathematical averages and may be very misleading in any assessment of a district's climate. This is particularly so in the case of marginal areas of production where average rainfall, for instance, may indicate the possibility or probability of profitable agricultural and pastoral undertakings; but where experience has proved otherwise. Within limitations, averages, of course, have their value; in fact they will be used in this review.

The general position in New South Wales is complicated by the fact that over a large portion of the State, rainfall is not seasonal, and dry or wet spells are likely to occur in, or extend through, any period of the year. On the average, of course, our northern districts receive the bulk of their annual precipitation in the warmer months of the year and the southern districts in the colder months. Even in these areas, however, the seasonal rainfall is not nearly so marked as in sections of other Australian States. Our coastal rainfall, although heavier than inland precipitation, is very erratic, and not infrequently a substantial proportion of the annual precipitation is received in a few days as the result of a cyclonic storm. Even in our far western areas heavy, but irregular and all too infrequent tropical rainstorms, are responsible for annual averages appearing more favourable than conditions mostly experienced.

Rainfall Reliability an Important Factor.

As already stated, data in the form of averages, be they monthly or annual, are more or less valuable within limitations for general purposes. For instance, they may be particularly so in connection with water conservation where the important factor is effective aggregate precipitation over a period. For agricultural purposes, however, it is more desirable to examine rainfall data, and other climatic factors for that matter, from the standpoint of reliability; that is, what conditions based on previous experience are likely to occur most frequently in the future. To reach anything like the optimum in this connection in New South Wales our rainfall would need to be considerably less erratic than it now is. A desirable end may be achieved to some extent, however, if rainfall, although irregular, tends to average out fairly evenly over a period; that is, if bad seasons are followed by better conditions, either at short or more lengthy intervals. If, on the other hand, rainfall, in the long run, is declining, and poor seasons are becoming increasingly in evidence, then any conception of climatic probability based on previous experience, is likely to vary from actual results according to the rate of decline.

Less Rain in Recent Years but Future Trend Uncertain.

It might here be stated that our correspondent's query cannot be answered either in the negative or affirmative. Meteorological observations in this State cover too short a period of time to enable one to make reliable deductions. The available facts, however, are interesting and lessons may be learned therefrom, even if we are unable to ascertain the real long-run trend. Examination of available data will show just how erratic rainfall is in this State, and should indicate the futility of depending at any period on the continuance of good seasons. The greater attention focused on agricultural and pastoral problems during the past few years has brought more into relief the true nature of the climate of a large section of our State. During the disastrous 1944 drought, for instance, many sections of the community blamed the settlers of our western districts for the arid and dust-swept conditions of that portion of New South Wales. Rainfall statistics indicate that our pioneers were only partly to blame, and any reproach which may be their due should be shared by the community as a whole. In this connection it will not be out of place, and may be of some satisfaction to our correspondent, to mention briefly that, compared with earlier records, rainfall during recent years does show a definite falling off over a large area of the State. This, of course, is in no way a contradiction of the statement at the commencement of this paragraph regarding our inability to gauge the long-run trend.

Recent Dry Spells and the Cyclic Theory.

To an agricultural country rainfall data are always, or should always be, of particular interest. It is possible, however, that we have reached one of those points in our meteorological history which is more interesting than usual. We know by now that recurrent droughts are a feature of our climate rather than an exception, but that they are of variable extent and severity. We carry on as usual, however, in the expectation that sooner or later

they will be followed by better seasons. It is probable that the community generally holds the view, and not without some justification, that in the long run conditions average out, and that we should not be unduly pessimistic regarding the future. It is no light matter, however, when we contemplate that millions of souls are facing starvation through adverse seasonal conditions in many parts of the world. That stage has not been reached in Australia, but we have been rudely shocked several times of late to see that what "could not happen here" was actually closer to occurring than could have been thought possible only a few years ago.

During the last decade, subnormal rainfall has been more evident than above average precipitation and the 1944 drought was probably about as disastrous as this State has experienced in its known history. The dry period has been interspersed with good seasons; but these have been all too brief. In many instances the incidence of rainfall has been most unfavourable and much of the annual precipitation has been accounted for by heavy to flood falls over a relatively short period, which, incidentally, have occasioned considerable damage as well as relieving water shortages. The present under-average period of rainfall is possibly just another phase in our climatic make-up. It is probably different from any experienced during the keeping of official records, but not necessarily different from phases occurring in earlier history. The writer prefers the term "cycles" to "phases," but the existence of cycles in the sense that similar meteorological conditions tend to recur at more or less regular intervals is not proved. It is only fair to state, however, that their existence is not definitely disproved, and examination of some periods indicates that there may be some justification for the theory. It is interesting to note that Sturt, writing of his inland journey in 1828, expressed the opinion that the climate of New South Wales was delightful but too dry. He mentioned the recurrent droughts and stated that "from observations of former writers, seasons during which no rain falls appear to occur every ten or eleven years. Rains in first year after drought are excessive in duration, then they decrease gradually year after year, until they wholly cease for a time." The year 1826 saw the "commencement of one of the fearful droughts" which apparently continued until 1828.

Scantier Precipitation a Future Possibility.

If rainfall variability does not follow some regular sequence, it is obvious that droughts and good seasons are haphazard in their occurrence, in which case the future must always be very uncertain. Even if the cyclic theory could be held to be correct, available data are too meagre, and the period covered too short, for us to rest assured regarding either the immediate or more distant future. This leads up to the possibility that at some future time we may experience a period of very low rainfall, disastrous in the extreme. For indication that this is always a possibility it may be interesting, before reviewing the New South Wales data, to examine briefly some of the experiences elsewhere, also certain aspects of climatic change.

Climatic Changes in Past Ages.

An examination of the geological record of the world indicates that, throughout the ages, its climatic experience has been characterised by two broad patterns, namely, normal and glacial. The characteristic of glacial climates is the existence of frozen seas during the summer in polar regions, as is the case to-day. From the geological standpoint the absence of polar ice is the characteristic of normal times. The difference between normal and glacial climates is sharply defined, and transitions from one to the other occupied an inconsequential interval of time; geological time, of course.

World To-day in Interglacial Stage.

Normal climates prevailed during normal geologic periods, or times of quiet between revolutions, or periods of crustal unrest. As already indicated, we are living in a glacial period and, incidentally, in a time of crustal and climatic violence. Evidence shows that transitional periods are not even and during an ice age there may be several stages of ice advance, or glacial stage, separated by important stages of retreat, or interglacial, and numerous lesser swings. The world to-day is at the close of an ice age, but it is uncertain whether we are now experiencing an interglacial stage or the actual ending of the whole ice age. Some of the interglacial stages of the past have come closer to normal geological climates than that of to-day, and some of them had greater duration than the "recent" epoch. Even during the recent period there has not been a constant retreat in ice fronts, and there have been minor advances within historic time.

Delicate Balance Between "Normal" and Glacial Climates.

It would appear that the balance between normal or glacial climates is a delicate one. To a great extent it is dependent upon the existence or otherwise of the polar cap. The effect of an open Arctic Ocean, for instance, would be that of adding area to marine climatic influences, but a polar ice cap has an effect similar to addition of continental area, which makes for comparatively rapid and violent changes in temperature. It is held that a change from open to ice-capped polar seas may be caused by a surprisingly small variation in temperature. Once the sea freezes in winter and summer melting is insufficient to offset this freezing an ice cap will form. The growth at first will be slow, but after its radius has reached about 600 miles the growth of the ice becomes rapid because ice itself has a cooling effect on surrounding areas. Growth continues until the ice extends so far from polar areas that it encounters temperatures sufficiently high to prevent further extension. Glacial climates have their optimum development at such times. Rising temperatures cause the ice to retreat in reverse pattern. It has been calculated by one authority that the lowering of polar temperatures 5 degrees Fahrenheit under freezing point ultimately results in a drop of 50 degrees in polar winter temperatures, because of the cooling effect of the ice itself; and a rise of 2 degrees in the temperature of the earth now would be sufficient to clear polar seas of all ice. It will thus be seen how delicate is the balance at the present time between normal and glacial climates.

The detailed story of climatic changes during the several advances and retreats of glaciers is so complex that it still baffles experts. It is not known whether advances of ice were simultaneous in both hemispheres or even whether the advances were equal in extent over various portions of the continents. This links up with the incidental question of whether evidences of climatic change in certain localities can be accepted as indicating similar alterations throughout the world. The very important factor to remember regarding our climate is that, while it is still glacial rather than normal, the "recent" epoch of the geologist is a time of waning glaciation, rising seas and a return towards normal climatic patterns.

The Climate of Past Normal Periods.

There is considerable evidence regarding the extent of some of the ice advances. It is likewise known that this world has witnessed a general climate considerably different from that prevailing to-day. This was the normal period of genial climatic uniformity when conditions were relatively mild, mountains low and seas widespread. (It has been estimated that at the time of maximum advance of the last ice age, sufficient water had been evaporated out of the oceans and locked up as ice on the continents to lower general sea levels about 300 feet. Complete melting of the present Greenland and Antarctic ice caps would result in raising sea level another 100 to 160 feet.) Extremely low winter temperatures were unknown and distinctions between tropical and polar regions were less evident than at present. Climatic zones of animal and plant life existed, but contrasts between zones were not great. Continents were smaller and the atmosphere humid. Oceans were much warmer but it is probable that the tropics themselves were only slightly warmer than at present.

Adequate Precipitation in "Normal" Times but No Rain?

With regard, however, to the contrast between the amounts of precipitation received during normal or glacial times the position is not at all clear. Some interesting conjectures have arisen in the writer's mind. It seems that precipitation increases during major or minor trends towards a glacial advance and decreases during an interglacial trend; or that generally colder conditions induce greater rainfall, and increasing temperatures lighter precipitation. If this theory is correct it is not unreasonable to expect little or no rain during normal times, as we see how delicate is the balance even now between drought and wet conditions. It is accepted that precipitation was less in normal times owing to fewer and lower mountains and less sharply defined fronts between air masses which cause rain. The writer holds the view, however, that precipitation in normal times, or under conditions approaching such times, was probably relatively more adequate than it is now; the explanation being that precipitation did not occur in the form of rain at all—at least not over a substantial proportion of the earth. In any case the main belt of storminess would be centred well toward the poles. From our experience rainfall provides a very unsatisfactory way of watering the earth. It rarely meets our exact requirements and from a universal standpoint is mostly too heavy or too light. It is probable that moisture

requirements could be met more effectively after the manner mentioned in Genesis: "For the Lord God had not caused it to rain upon the earth . . . But there went up a mist from the earth and watered the whole face of the ground." If the writer's interpretation is correct, precipitation by this method seems quite feasible when we consider the probable atmospheric conditions prevailing in normal times. To a limited extent it occurs to-day. Dew, mist and fog are deposited in measurable quantities at times, and the amount of condensation which trees can induce under certain conditions, even in dry times, is surprising.

Adverse Times Ahead; But Good Conditions Eventually?

It will thus be seen why it is possible for our rainfall either to decrease or increase very materially from average expectations. Any diminishing trend must have serious repercussions. The outlook, however, even in such an eventuality, is not without hope. An interglacial stage may mean increasing warmth and lower rainfall; but it is apparent that eventually a stage is reached when other factors of a beneficial nature commence to operate. Frankly, it is the writer's view that the peoples of this world will experience some extremely adverse meterological conditions in the future, but only for a relatively short period. Then the "desert shall rejoice and blossom as the rose."

Climatic Changes During Present Glacial Retreat.

Before closing this section of the review it may be of interest to examine briefly some of the evidence of climatic change during the present epoch of retreat of continental glaciers, the Recent. It is thought that the last general recession began about 30,000 to 40,000 years ago, and in north-western Europe the Arctic period (extreme glacial climates) had by 12,000 B.C. gradually passed into the subarctic period. Accelerated melting about 8,000 B.C. permitted the entrance of the saline Atlantic into the Baltic. A northern (Boreal) climatic period followed in Central Europe, and forests pushed northward as its intensity diminished. By about 5,000 B.C. the Baltic became warm enough to support types of life that demand temperatures warmer than those of to-day. From 5,000 to 3,000 B.C. conditions were warm and moist (Atlantic period), and temperatures were sufficiently high to cause all the small glaciers of the Alps and those now present in the United States to disappear completely. This period was followed about 2,000 B.C. by the dry and warm Subboreal which lasted well over a 1,000 years. During this period houses were built in marshy places which later became lakes. The dryness, however, was not continuous as the lake villages in Switzerland were destroyed by flood in 1275 B.C. Increasing rainfall and cooler weather followed in western Europe (Subatlantic), typical development being reached between 850 and 350 B.C. A precipitation maximum is indicated in North America, Africa, Western Asia and Europe generally. All these places, however, record very dry conditions about 700 A.D. Evidence of world-wide climatic swings is considerable, although records indicate some notable exceptions, particularly between European and Chinese precipitation.

Precipitation conditions during the first century A.D. over Europe and south-western Asia appear to have closely resembled those of to-day. From about A.D. 180 to 350 Europe experienced a wet period. The fifth century was dry in Europe and western Asia, and apparently also in North America, where many lakes in western United States appear to have dried out completely. During the seventh century glaciers in Europe retreated to such an extent that heavy traffic used alpine passes now closed by ice. The beginning of the ninth century brought heavier precipitation to Europe. The level of lakes rose and the inhabitants of their borders were pushed upslope. Documental evidence from south-western Asia and American tree rings give similar testimony. Warm, dry conditions returned during the tenth and eleventh centuries. This was the time of great exploratory activity among north-western Europeans. The logs of Greenland voyagers show routes of travel where they would now be impossible because of ice floes. Greenland was settled in 984 and abandoned in about 1410. The first half of the thirteenth century was a period of great storminess, and the early fourteenth century was unusually cold and wet. The Aztecs settled in Mexico in 1325 when lakes stood at levels higher than those of to-day. Drought and lower levels followed, but in 1550 lakes again reached high stages. The early seventeenth century in Europe was particularly wet. Alpine glaciers extended far down valleys, and northern Italy suffered from disastrous floods. Glaciers retreated between 1640 and 1770, and then advanced until the middle of the nineteenth century. Since then they have retreated back to the sixteenth century positions. This appears to be a world-wide conditions and suggests higher summer temperatures during the last century.

Recent Temperature Trends.

The United States Weather Bureau recently announced, according to a press report, that the weather of the world had become warmer during the past fifty years. Since 1940, however, there had been a slight downward trend in America. This is probably the position in New South Wales. As far as can be ascertained by the writer, we do not appear to receive the same amount of snow as formerly during the winters The widespread fall in June last, particularly in the south-east quarter of the State, was a noted exception. January, 1939, was a month of terrific heat and record high temperatures in many districts, Sydney's reading reaching 113.6 degrees. Summers have since been variable, but the last was very hot, and for the first time on record Sydney recorded consecutive centuries. It will thus be seen how easily man's life on this planet can be affected by climatic changes, particularly if no effective steps are taken to cope with the altering conditions.

What New South Wales Rainfall Data Show.

For the purpose of examining trends of rainfall in New South Wales the following graphs have been prepared indicating, in respect of twenty-six centres, average annual precipitation over periods of ten years since the keeping of records. The graphs total eight and show the position for (1) the North and Central Coast, (2) Metropolitan and South Coast, (3) Tablelands, (4)

Slopes, (5) Plains, (6) Riverina, (7) Western Upper and (8) Western Lower sections of the State. The centres shown in each section were selected having regard to the availability of data and their representative importance. The periods covered vary, and in a few instances the early sections do not contain the complete ten-year figures. The graphs, of course, do not show the variability of rainfall from year to year, which, as already indicated, can be very considerable. Bourke, for instance, received 2,577 points of rain in 1936, but only 470 in 1935. The ten-year averages, however, are reasonable for the purposes of this review as indicating trends since registrations were recorded.

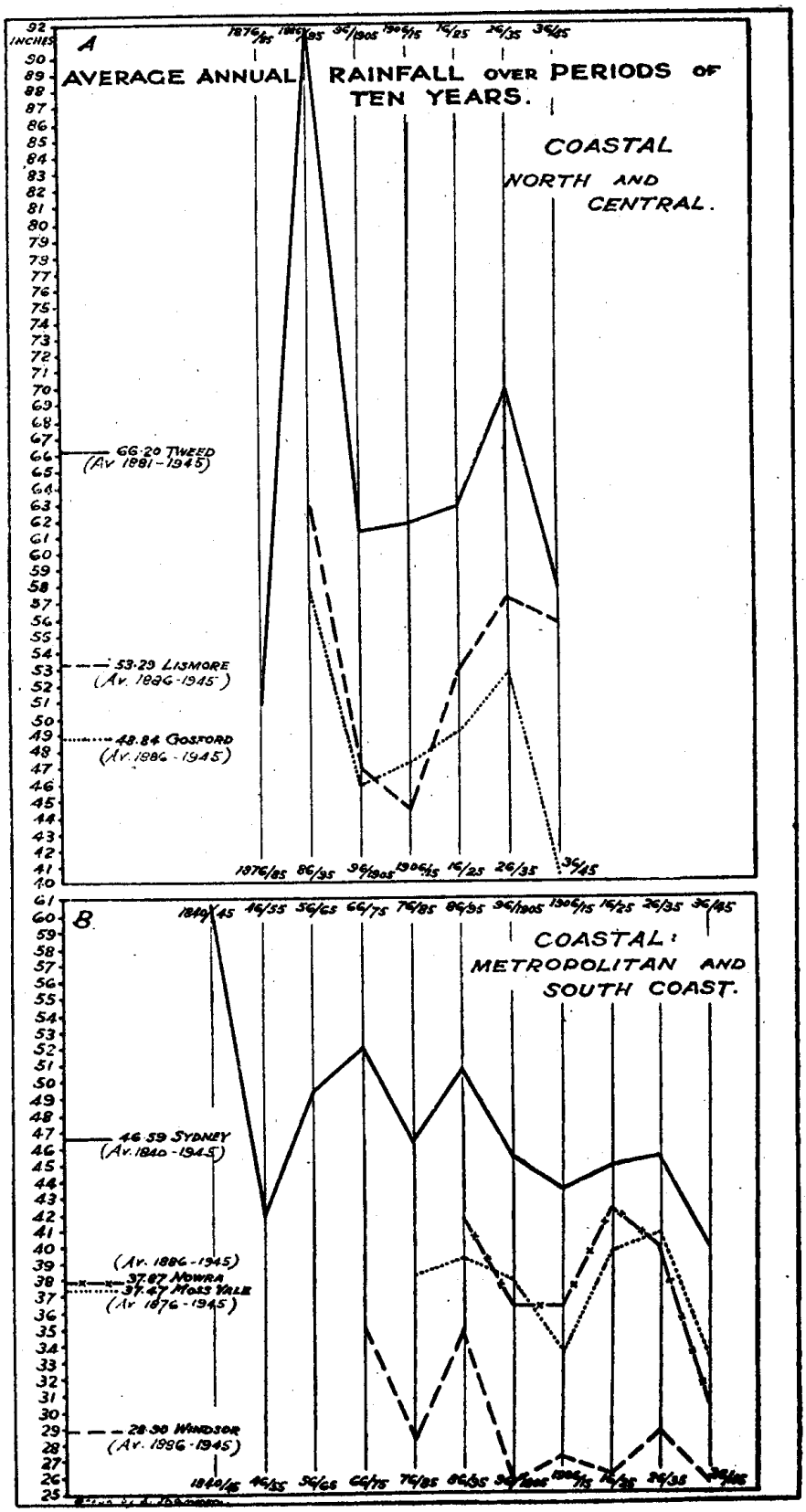
For the benefit of those not familiar with rainfall distribution in New South Wales it may be interesting to point out that, generally speaking, precipitation is heaviest on the North Coast and tends to decrease as we proceed southward and westward. There are exceptions, however, to the decrease as latitude increases, as the experience in the Western sections will show.

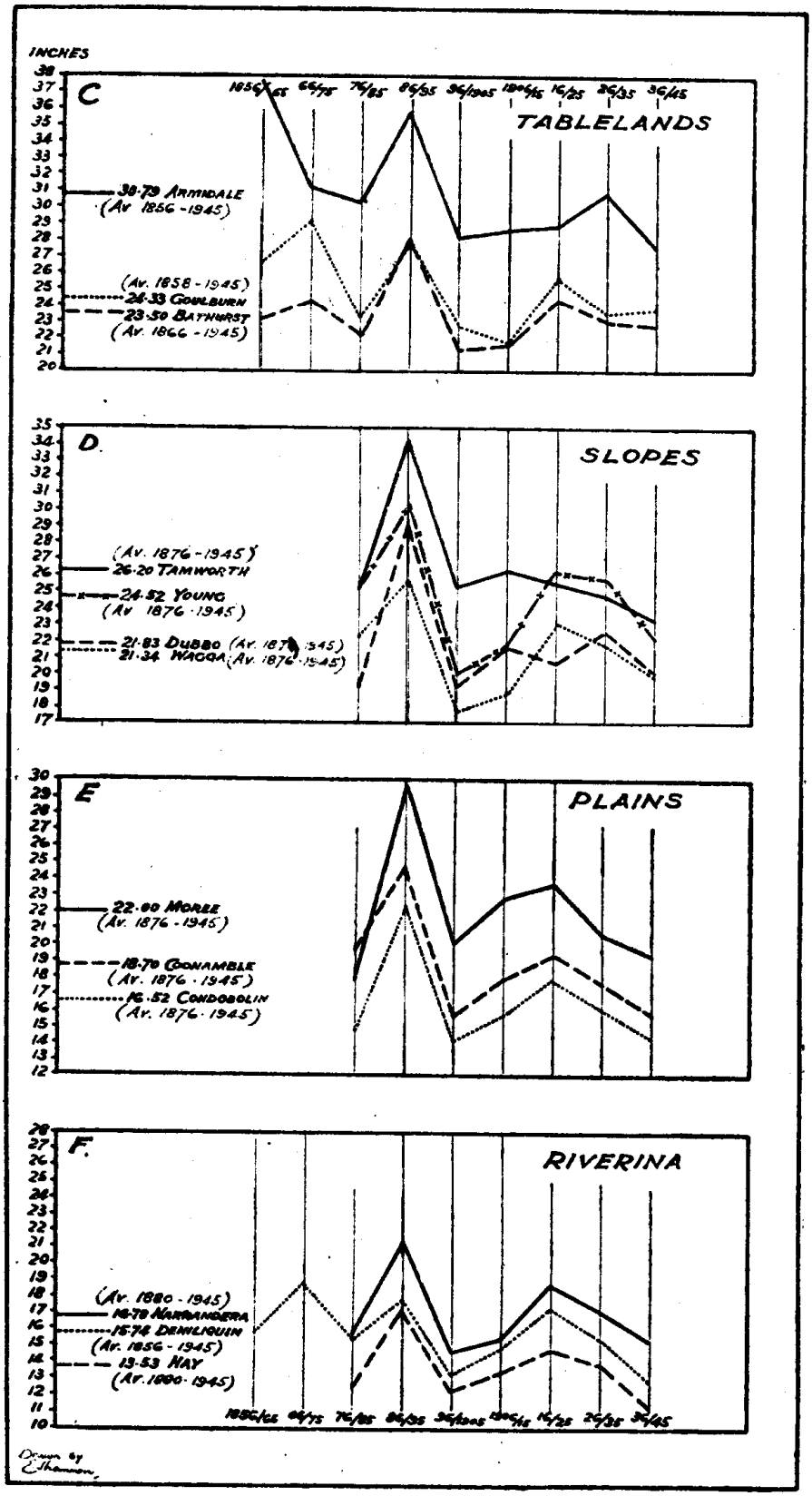
Referring now to the graphs we notice several outstanding features. Naturally, being concerned with the present position we are struck firstly with the decline over the last twenty years at most centres. Precipitation for the last available period, 1936-1945, shows a downward trend for all centres, except Goulburn, Bourke and Ivanhoe. Goulburn, however, had rainfall well above average in 1936 and 1943; Bourke had abnormally heavy rain in 1936 (see previous note); and Ivanhoe abnormal falls in 1936 and 1939. The next important feature is that the 1936-45 period shows rainfall lower than the average at all centres except Lismore (actual average over all years at each centre is shown on graphs, e.g., Sydney, 46.59, or 46 inches 59 points). The third important feature is that the 1936-45 rainfall was the lowest on record at thirteen of the representative centres. Where this was not so, it was mostly very little above the lowest figure.

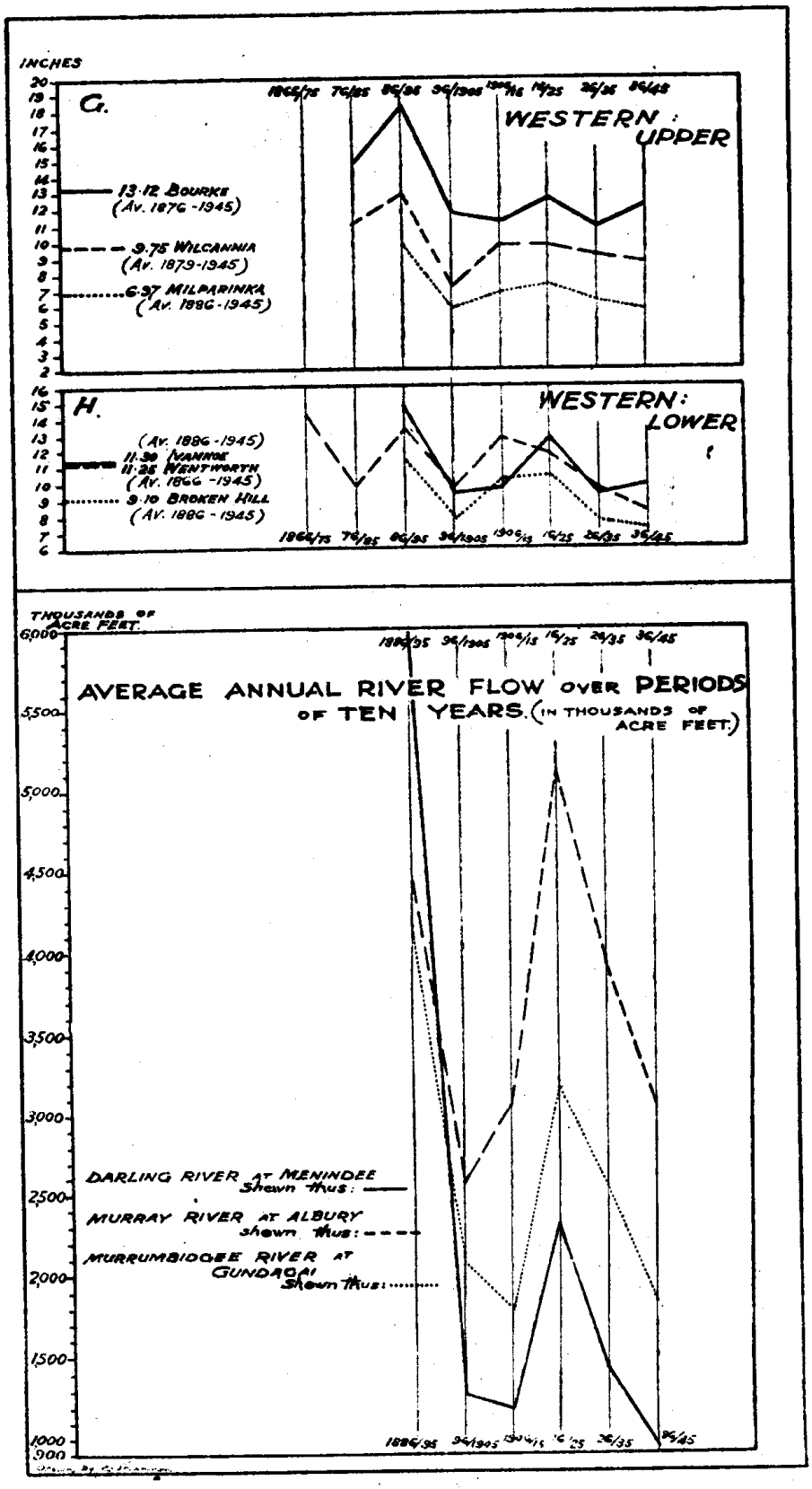
Fifty Years Since Last Generally Wet Period.

It will be noticed that the last really wet period, or relatively so, was that of 1886-95, and that experience has since been repeated only at Nowra and Moss Vale, on the South Coast (note remarks re temperature trend). Where records are available it will be seen that wet periods occurred prior to the 1886-95 decade.

Compared with the average experience some of the coastal centres and inland districts, such as Bathurst, Goulburn and Wagga were faring fairly well until the last decade. Gaugings in the Bathurst and Goulburn districts, particularly the former, appear to have varied very little comparatively. Indeed, examination of Bathurst's rainfall since 1866 would not indicate that any decline was taking place. This condition, however, could not be said to apply to many other areas of this State where the position is only too obvious, as the graphs indicate. Bathurst, of course, is located in an area which is likely to receive rain from most of the storms which affect this State. Other areas are only affected by certain types of storms, and these may decline in intensity and frequency in some parts of the continent and not in others.


A
AVERAGE ANNUAL RAINFALL OVER PERIODS OF TEN YEARS.
COASTAL NORTH AND CENTRAL.
INCHES
66·20 TWEED (Av 1881-1945)
53·29 LISMORE (Av. 1886-1945)
48·84 GOSFORD (Av. 1886-1945)
1876/85 86/95 96/1905 1906/15 16/25 26/35 36/45
B.
COASTAL: METROPOLITAN AND SOUTH COAST.
46·59 SYDNEY (Av. 1840-1945)
(Av. 1886-1945)
37·87 NOWRA
37·47 MOSS VALE
(Av. 1876-1945)
28·90 WINDSOR (Av. 1896-1945)
1840/45 46/55 56/65 66/75 76/85 86/95 96/1905 1906/15 16/25 26/35 36/45


INCHES
C
TABLELANDS
38·79 ARMIDALE
(Av 1856-1945)
(Av. 1858-1945)
24·33 GOULBURN
23·50 BATHURST
(Av. 1866-1945)
D.
SLOPES
(Av. 1876-1945)
26·20 TAMWORTH
24·52 YOUNG
(Av 1876-1945)
21·83 DUBBO (Av. 1876-1945)
21·34 WAGGA (Av. 1876-1945)
E
PLAINS
22·60 MOREE
(Av. 1876-1945)
18·70 COONAMBLE
(Av. 1876-1945)
16·52 CONDOBOLIN
(Av. 1876-1945)
F.
RIVERINA
(Av. 1880-1945)
16·78 NARRANDERA
16·74 DENILIQUIN
(Av. 1856-1945)
13·53 HAY
(Av. 1880-1945)


INCHES
G.
WESTERN: UPPER
13·12 BOURKE (Av. 1870-1945)
9·75 WILCANNIA (Av. 1879-1945)
6·37 MILPARINKA (Av. 1880-1945)
H.
WESTERN: LOWER
(Av. 1880-1945)
11·30 WANAAING
11·25 WENTWORTH (Av. 1866-1945)
9·10 BROKEN HILL (Av. 1880-1945)
THOUSANDS OF ACRE FEET.
AVERAGE ANNUAL RIVER FLOW OVER PERIODS OF TEN YEARS. (IN THOUSANDS OF ACRE FEET.)
DARLING RIVER AT MENINDEE Shewn thus: ——
MURRAY RIVER AT ALBURY shewn thus: - - - -
MURRUMBIDGEE RIVER AT GUNDAGAI Shewn thus: .....

New South Wales River Flows.

In addition to the rainfall graphs one has been added indicating, as a matter of interest, the average annual flow of water in thousands of acre feet, since records were taken, in the Darling, Murray and Murrumbidgee Rivers, for similar periods. Note how the flow of the Darling has declined in recent years, compared with the 1886-95 position. The water level, however, must have been very low during the 1826-1828 drought.

Conservation and Co-operation Imperative.

It will be seen that the general position in New South Wales is not a very satisfactory one. Precipitation data show a downward trend over a wide area of the State and, as already indicated, it is possible that the decline may continue. It is to be hoped, however, that the recent trend has run its course and that a more favourable one will commence in the near future. Whether or not favourable conditions lie ahead, it seems quite clear from a brief examination of this State's rainfall data and the world's climatic experience generally, that we cannot afford to take the slightest avoidable risks in the future, in the hope that better times cannot be far off and must come eventually. It is imperative that we take all possible steps, within reason, to conserve and make the best use of what rainfall is received; also that we co-operate closely with the natural elements in planning economic policies, and not independently of them.

NOTE.—The Divisional Meteorologist (Mr. B. W. Newman) concurs in the views expressed in this article.

A SURVEY OF THE NAVY BEAN INDUSTRY IN NEW SOUTH WALES.

BY

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Production of navy beans on a commercial scale in Australia was begun as recently as 1940. Since that year, the industry has become well-established, particularly in New South Wales, where the navy bean crop now forms an important feature of the agriculture of the New England district.

Establishment of the Industry.

The establishment of this industry, like many others, was the result of curtailment of supplies from overseas. As navy beans provide a rich source of protein, they were required in large quantities in both dried and canned forms by the Allied Services in Australia. Therefore, up to the present time, the industry has been under the control of the Commonwealth Government which arranged contracts with the growers, supervised the cleaning and grading of the beans at Guyra and organised the distribution of the beans between the Services and the civilian market.