DISCLAIMER

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§ 7. The Climatic Factors Influencing Settlement in Australia.*

1. **Introduction.**—There is an impression among some Australians that the climate of the continent does not vary to any great extent from one end to the other. Of all the large land masses, Australia has probably the least average elevation and the most unbroken coastline; both of these conditions make for uniformity. But the area of the continent is very large, and it lies in one of the most variable climatic belts on the earth's surface. It would, therefore, be a serious error to judge the Australian climate only by the southern types thereof, with which alone, probably some three-quarters of the inhabitants are personally familiar.

It will be useful for comparison to glance for a moment at the better appreciated diversity of climates in the region lying between Britain and India. Facing the almost permanent westerly gales is the rugged west coast of Ireland. It receives a perpetual drenching from the moisture-laden winds, and the result is that Western Ireland has large areas of bog land and much deciduous forest, but is too wet for cereals. Somewhat similar conditions obtain in Western Tasmania. (See Fig. 1.)

Passing further to the south-east the Mediterranean lands are reached. Here is an absence of deciduous trees, their place being taken largely by evergreens. A sharply-marked winter rainfall, with considerable periods of drought, is experienced. The same features are characteristic of most of southern Australia. South of the Mediterranean the desert regions of the Sahara are bordered by a grassland belt watered by scanty winter rains, and these conditions also characterise the region of the new Trans-Australian railway. To the east of the Mediterranean, and somewhat remote from the sea, are the Steppes of the Caspian. These are to some extent paralleled by the Australian Riverina —though the latter is warmer.

The true desert of Sahara, with a rainfall below five or six inches, has its counterpart in the region around Lake Eyre, and perhaps in Western Australia. Nearer the Equator are the Savanna regions, grass lands watered by scanty summer rain. The Sudan is of this type, and it is represented in Australia by the inland regions along the Tropic.

The survey has now reached the tropical regions of India, which have a good monsoonal rainfall. Here a distinction should be made between the centre of the Peninsula with its well-marked winter drought, and the East coast. The former agrees in the matter of rainfall with Northern Australia, while the Madras coast resembles the North Queensland coast with a much heavier and more uniform rainfall.

In addition to the eight climatic regions already noted, there is a special type along the coast of New South Wales which differs somewhat from any so far touched upon. Its homoclimes are in China and Uruguay.

It would be quite proper to include Papua and Macquarie Island in a survey of the climate of the Commonwealth. Macquarie Island lies in 55° S. latitude, to the south of Tasmania, and its climate resembles that of Iceland. Hence one could extend the scale through the whole of the regions possessing tropical, temperate and sub-polar climates.

There can be little doubt that climate is the major factor in determining the permanent settlement of the various regions of the earth. It controls agriculture and grazing, which in their turn largely determine manufacturing industries. It controls comfort and health—very potent factors in the spread of white civilisations. In fact, were it not for certain valuable mineral deposits, one would find that practically all the main centres of white settlement could be defined in terms of temperature, humidity and rainfall.

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Similar controls, no doubt, operate in connection with the other races. Probably the black race flourishes within narrower limits, and the yellow race within wider limits than the white race; but a very short survey will shew that the Australian Commonwealth contains regions akin to those inhabited by types of each of the great races of mankind.

Thus there are in Australia, as shewn by Fig. 1, climatic factors such as are associated with all the following peoples and products :—

Nordic races as in parts of Ireland—tall, fair-haired men interested in pigs, potatoes and peat. Shorter Alpine "roundheads," as in Central France, concerned with sheep and cattle. Short dark Mediterranean people, as in Italy, busy with wheat, olives and wine. In the irrigated districts of Egypt are the Copts growing rice and cotton; while in the drier regions near by are the Syrians, concerned *inter alia* with tobacco and goats. In the true desert is the Tuareg, whose environment has made him a nomad. Belonging also to the "white race" are the Hindus of the North of India, who grow cotton, rice, jute, and oilseeds.

The yellow Kirghiz of the Caspian Steppes are pastoral nomads whose southern lands are becoming important cotton areas. Corresponding to the New South Wales coast is Eastern China with tea, maize and sugar cane grown by pure Mongolians.

The Savannas of the Sudan are peopled by negroes interested in cattle, millet and various gums. The South of India, containing dark Dravidians of uncertain origin, produces coffee, tea and tropical oilseeds.

Here, indeed, is a "diversity of creatures," whose whole scheme of life is largely determined by their environment. In Australia the environment is as diverse, and it is logical to assume that it will exert a potent, if slow, influence on Australians.

2. **Temperature.**—Early in the study of climatology it was discovered that the Southern Hemisphere is cooler than the Northern. This fact has been taken by many people to imply that Tropical Australia is much cooler than similarly situated regions in other continents. Moreover, it has been stated that the heat equator is confined to the Northern Hemisphere, and hence that only a mere coastal fringe along the north coast can properly be assigned to Tropical Australia.

The above general statements are true—but the deductions are wrong, for the reason that Australia is an exception to both rules. There is no mysterious virtue about the Southern Hemisphere—it is merely the great preponderance of ocean which keeps its average temperature low. But the few large land masses—of which Australia is one—are hot enough, as it is only too easy to shew.

TABLE I.—LATITUDE AND TEMPERATURE.

Latitude.	Average Temperature.*		Temperature in Australian Regions along 135° E. Long.	
	N. Hemisphere.	S. Hemisphere.		
	° F.	° F.	° F.	
0° ...	78.5	78.5	80	Tropic.
5° ...	79.0	77.9	80	
10° ...	79.5	77.0	82	
15° ...	79.4	75.7	81	
20° ...	78.0	73.0	76	
25° ...	74.7	69.7	70	Temperate.
30° ...	68.5	65.4	66	
35° ...	63.0	59.4	61	
40° ...	57.2	53.2	55	

* From Hann.

Note.—The last column shews smoothed temperatures along longitude 135° E., which fairly represent the "continental" portion of Australia.

Hence we see that Tropical Australia is not only hotter than the average for the Southern Hemisphere, but is hotter than the average for the Northern Hemisphere. It is indeed much hotter than any land between us and the North Pole. It is, therefore, obvious that the heat equator must be drawn through Northern Australia.

There are two further reasons why Australian climates have not been properly estimated in the past.

Almost all maps shewing world temperatures are so constructed that the effect of elevation is removed by reducing the temperature readings to sea level. Thus authoritative maps shew the city of Mexico as having an average annual temperature of 80° F., much the same as Broome, in the same latitude. But actually the average temperature of Mexico is under 60° F.; and the same applies to many other tropical areas. As will be seen later, no continent has so small a proportion of highlands as Australia.

Furthermore, if a tabulation is made of those localities having an average annual temperature over 84° F., it will be found that there are only four such regions of greatest heat recorded in the authoritative work by Hann.

TABLE II.—HOTTEST REGIONS OF THE GLOBE.

Region.	Average Temperature.	Average Rainfall.
1. Timbuktu and vicinity	84° F.	0-10 inches
2. Massowah to Khartum	86° F.	10-20 „
3. Tinnevelly in South India	84.3° F.	40-60 „
4. Wyndham in North-west Australia ...	84.6° F.	40-60 „

If the moistness of the heat be considered, it will be seen that Wyndham has an unenviable position among the world's climates—at any rate in the rainy season.

3. **Effect of Elevation.**—Large portions of the British tropical areas are, luckily, situated at high altitudes. Thus, in Rhodesia approximately 90 per cent. (some 400,000 square miles) is over 2000 feet above sea level. This lowers the temperature by about 7° F., and is a vital factor in regard to settlement. It will be interesting to see how the elevation affects settlement in Australia. In the Tropics there are only three areas which are worth considering.

TABLE III.—TROPICAL HIGHLANDS IN AUSTRALIA.

Tropical Highlands.*	Approximate Area over 2000 feet.	Per cent. of State or Territory.
A. Atherton Tableland, Queensland ...	12,000 sq. miles	2
B. Macdonnell Ranges, N. Territory ...	14,000 „	2.6
C. Fortescue River area, W. Australia ...	11,000 „	1

* The index letters correspond with those on Fig. 8.

Adding a few much smaller areas it will be found that only four per cent. of Tropical Australia is high enough to benefit in this respect. The result is that no injustice will be done if the Tropic of Capricorn be taken as truly representing the southern limit of the tropics in Australia.

As regards temperate Australia, there are but few noteworthy features in the distribution of temperature. Only in the east and south-east are the settled highlands extensive enough to be important.

The following tables give approximate areas for the temperate regions above 2000 feet in Eastern Australia. These all have an adequate rainfall:—

TABLE IV.—EASTERN TEMPERATE HIGHLANDS.

Well-watered Highlands.*	Approximate Area over 2000 feet.	Rainfall.
D. Darling Downs and Tambo Downs, Queensland	2,300 sq. miles	30 inches
E. New England Plateau, N. S. Wales, including Macpherson Ranges ...	23,500 ,,	35 ,,
F. Blue Mountain Plateau, N. S. Wales	14,800 ,,	30 ,,
G. Monaro Plateau, N. S. Wales ...	13,300 ,,	25 ,,
H. Victorian Highlands, Victoria ...	7,700 ,,	50 ,,
J. Tasmanian Highlands	4,400 ,,	40 ,,
	66,000 ,,	...

* The index letters correspond with those on Fig. 8.

Of less important temperate highlands—all situated in regions of low rainfall—there are several in other States.

TABLE V.—DRY TEMPERATE HIGHLANDS.

Dry Highlands.*	Approximate Area.	Estimated Rainfall.
K. Flinders Range, S. Australia ...	1,300 sq. miles	10 inches.
L. Musgrave Ranges, S. Australia ...	6,300 ,,	10 ,,
M. Macdonnells (temperate), N. Territory	7,600 ,,	9 ,,
N. Wiluna Highlands, W. Australia ...	11,600 ,,	9 ,,
O. Ashburton Highlands, W. Australia...	21,200 ,,	9 ,,
	48,000 ,,	...

* The index letters correspond with those on Fig. 8.

There are a few other small areas, such as the Stirling Range, Western Australia, which average less than 1000 square miles each—so that the total highland areas of Australia may be summed up as follows:—

TABLE VI.—AUSTRALIAN HIGHLANDS OVER 2000 FEET.

Tropical—Dry	25,000 sq. miles	40,000 sq. miles
Wet	15,000 ,,	
Temperate—Dry... ...	48,000 ,,	114,000 ,,
Wet ...	66,000 ,,	
Total		154,000 ,,

This is a very small proportion (about five per cent.) of the total area of the Commonwealth.

4. **Range of Temperature.**—The range of temperature during the year depends on two factors; distance from the coast, and distance from the Equator. Both of these operate to increase the range. There is nothing unusual in the range of temperature in Australia, but it has considerable bearing on the health and comfort of the inhabitants, and so deserves a brief mention. (See Fig. 2.) The isopleth for a range of 15° F. almost agrees with the southern coastline; while the 20° isopleth runs along the east from Mackay to Gabo Island, and along the west from Perth to Broome. The north coast is bathed by tropical seas and the range is very little, usually about 10°.

The highest range occurs in a central belt between Bourke and Wiluna, at each of which the temperature of the coldest month is 33° degrees below that of the hottest month. The other isopleths run in concentric fashion around this central belt of high range.

In the cooler regions an equable climate is often desirable from the point of view of health. The following table shews many favourable localities :—

TABLE VII.—TEMPERATE LOCALITIES WITH LOW RANGE.

Locality.	Range.	
Breaksea Island, Western Australia ...	11.0° F.	
Cape Leeuwin, ,, ...	11.8° ,,	Difference between
Cape Sorell, Western Tasmania ...	12.0° ,,	average temperature
Cape Otway, Victoria	12.3° ,,	of hottest month and
Wilson's Promontory, Victoria ...	13.8° ,,	average temperature
Robe, South Australia	13.9° ,,	of coldest month.
Gabo Island, Victoria	14.4° ,,	

In the tropics, however, a large range is always advantageous, and this is only experienced away from the coast. (As will be seen, the humidity unfortunately follows the same rule.) Hence, during the cooler months of the year, in the inland tropical regions the climate is delightful. But on the north coast the range is reduced to a minimum, as the following table shews :—

TABLE VIII.—TROPICAL LOCALITIES WITH LOW RANGE OF TEMPERATURE.

Locality.	Range.
Thursday Island	5.5° F.
Darwin	8.2° ,,
Cooktown	9.9° ,,
Cairns	11.9° ,,

Almost all the region north of 18° S. latitude (Broome to Daly Waters to Mackay) experiences a range of less than 18° F.

5. **Humidity.**—Humidity is an element which requires somewhat more elaborate apparatus for recording purposes than do temperature and rainfall, hence it is not so generally recorded. However, the Commonwealth has a very well distributed corps of observers, and Australia is, in consequence, one of the first continents to be adequately mapped in this respect. (See Fig. 3.)

MEAN MONTHLY HUMIDITY.

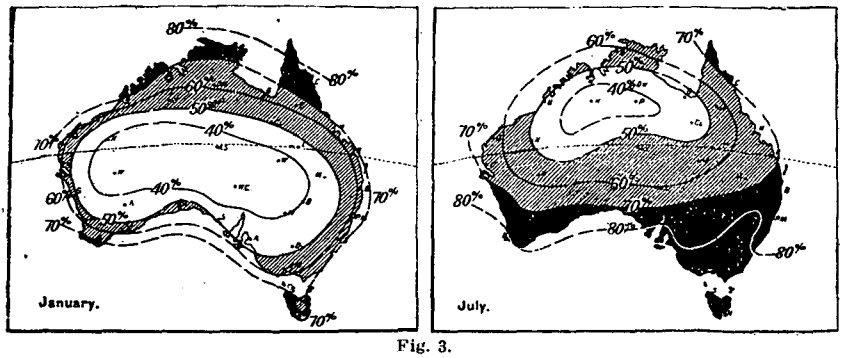

Fig. 3.

If the relative humidity for each of the twelve months be plotted for Australia, it is found that the isopleths are concentric, and more or less parallel with the coastline. The "centre of minimum humidity" moves north and south with the sun, being near Powell's Creek, Northern Territory, in June, and in higher latitudes in summer. There seem indeed to be two summer "centres," one just north-east of Lake Eyre, and the other north-east of Wiluna. These districts have long been known as Sturt's Stony Desert and Gibson's Desert respectively, and it is probable that the association is by no means accidental.

The two extreme months are June, when the general humidity is greatest, and October, when it is least. Luckily, in Australia by far the greatest area of high humidity occurs in winter in the cooler southern portion of the continent. (This is, of course, directly related to the fact that the southern rains occur chiefly in winter.) Here the high humidity has no harmful effect on the population, and may be beneficial to crops.

There is, unfortunately, a season of high humidity in the tropics, and it is this which is of great interest in considering the effect of climate on settlement. It is usually granted that the tropical regions having, in the warm season, a mean monthly humidity exceeding seventy per cent. are distinctly uncomfortable to live in, even if this be not positively injurious to the stamina of the race.

Considering the six hottest months only (from November to April, inclusive), the following tropical stations, together with the intermediate areas, are the most humid. All occur along the north or north-east coast :—

TABLE IX.—HIGH RELATIVE HUMIDITY IN AUSTRALIAN SUMMER.

Locality.	Nov.	Dec.	Jan.	Feb.	March.	April.	Average Summer.
	%	%	%	%	%	%	%
Broome ...	59	67	71	72	66	56	65
Wyndham ...	62	65	68	69	65	50	63
Darwin ...	67	71	77	79	75	70	73
Thursday Island	67	71	82	83	85	77	77
Cairns	69	71	76	75	74	76	73
Townsville ...	69	73	73	73	71	67	71
Brisbane ...	59	62	66	70	72	73	67
Sydney ...	67	67	70	72	75	77*	71*

* In April Sydney is cool enough to nullify the high humidity.

6. **Rainfall.**—There is no doubt that rainfall is the chief factor governing settlement in Australia as in other temperate regions of the world. In the United States, the relation between the 20-inch isohyet and the population isopleth is striking. All to the east (over twenty inches) has over six persons per square mile, almost all to the west (under twenty inches) has less than two persons per square mile.

The average annual rainfall map† is now fairly complete except in the central belt across Western Australia, where rains are very variable and records short or wanting. But this map alone gives a very incomplete statement of the value of the rains. Thus, each of the four following stations has a rainfall of about fifteen inches per year; but the settler would make a grave mistake if he assumed that the rains were all of the same type:—Roebourne (lat. 21°) and Northam (lat. 32°) in Western Australia, Tennant's Creek (lat. 20°) in Northern Territory, and Cobar (lat. 32°) in Central New South Wales, have all annual totals of fifteen inches. None of these is debarred from settlement by excessive heat or dryness, but two of them will never support a large population.

The Roebourne region is marked by the most unreliable rainfall in Australia. In 1891 it received only 0.13 inches, while in 1900 there fell 42 inches. Tennant's Creek is chiefly characterised by a totally dry period of seven months, which extends from April to

† See article by H. A. Hunt, Esq., F. R. Met. Soc., Commonwealth Meteorologist, in this Year Book p. 56.

October. Cobar receives its fifteen-inch rainfall spread out almost uniformly through the year. Northam, Western Australia, obtains practically all of it during the wheat period, and is consequently a much more important farming region than Cobar, which is only barely within the dry-farming area.

It is, therefore, obvious that the season at which the rain occurs, and the certainty of its occurrence, are matters as important as the total amount. Hence it is appropriate to base the classification of the climatic regions on a consideration of these factors.

7. **Rain Reliability.**—From the previous section it will be seen that in some regions of Australia the rainfall is more reliable than in others—quite irrespective of the total amounts. Thus, the twenty inches that the wheat farmer can expect to receive with some certainty in the Katanning district, Western Australia, is much more valuable than the twenty inches which may fall in the course of a few days at Wiluna, Western Australia.* To obtain the rain reliability map shewn in Fig. 4 the following procedure was adopted :—

A table of annual rainfalls for twenty years (1891-1910) was consulted. At each of the localities listed the departures from the normal rainfall were obtained. These departures (ignoring sign) were then averaged and the result expressed as a percentage of of the total rainfall. Thus (taking a striking example), the average rainfall at Onslow, Western Australia, is about eight and a-half inches, but it has varied from one inch in 1896, to twenty-seven inches in 1900. The average of all such departures is five inches, and this is inserted on the map (as a percentage of eight and a-half inches) as sixty per cent.

The map shews two "poles." Near Perth, Western Australia, is the most reliable region, where a variation of less than ten per cent. from the average is all that is likely. All along the south coast the variation is of the order of fifteen per cent., and thence becomes greater as one proceeds north and north-west. The maximum variation or least reliability, occurs at Onslow, sixty per cent., and Charlotte Waters, fifty-seven per cent.

Most of the north coast shews a variation of twenty per cent., or moderate reliability, and the same is true for the east coast. A region of unexpected unreliability is the Barkly Tableland, which seems to vary by about forty-five per cent. In fact, all the cooler portions of the Northern Territory have a very unreliable, as well as a low, rainfall; and this chart certainly indicates that agriculture without irrigation will always be a risky speculation anywhere in the inland portions of the Northern Territory and of Queensland.

It explains, also, why a low average rainfall of ten inches in Swanland, south-west Western Australia, and Eyre's Peninsula is able to give better crops than ten inches in Victoria or New South Wales. It is much more to be counted on in the south-west than in the south-east.

It is to be noted that in the arid interior receiving less than ten inches per year the warmer northern portion has a much more erratic rainfall than the southern cooler portion. Since, moreover, evaporation is so much greater in the northern moiety, this leads to the vegetation and pasture being less scanty in the south than it is along the same isohyet in the north.

8. **Rain Regions.**—Two further rain boundaries deserve discussion. The chief is of course that separating the region of winter rains from the region of summer rains.† (Fig. 5.) The winter rains are, speaking generally, associated with the westerly winds of the Antarctic depressions. These latter Lows travel eastwards along tracks which depend on the season, i.e. on the declination or the apparent track of the overhead sun. They affect Australia chiefly in winter.

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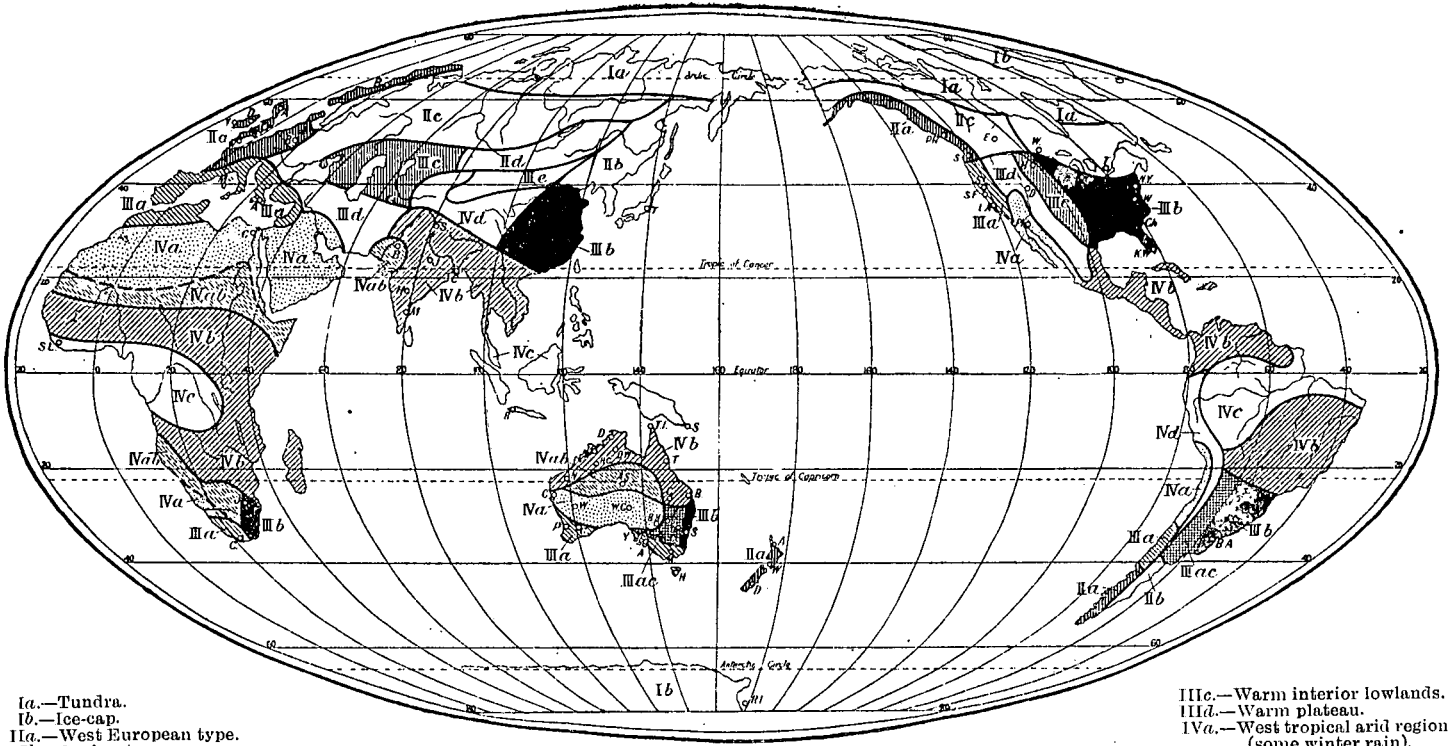
* *Vide* "The Australian Environment," Griffith Taylor, 1918.
† See H. A. Hunt, Bulletin 4, Melbourne, 1909.



Reference.

Fig. 1.

Ia.—Tundra.
Ib.—Ice-cap.
IIa.—West European type.
IIb.—Quebec type.
IIc.—Siberian type.
IId.—Rockies type.
IIIa.—Mediterranean type.
IIIac.—Murray basin type.
IIIb.—Warm eastern margin
IIIc.—Warm interior lowlands.
IIId.—Warm plateau.
IVa.—West tropical arid region (some winter rain).
IVab.—West tropical arid region (some summer rain).
IVb.—Monsoon and Sudan type.
IVc.—Equatorial lowlands.
IVd.—Hot plateau.

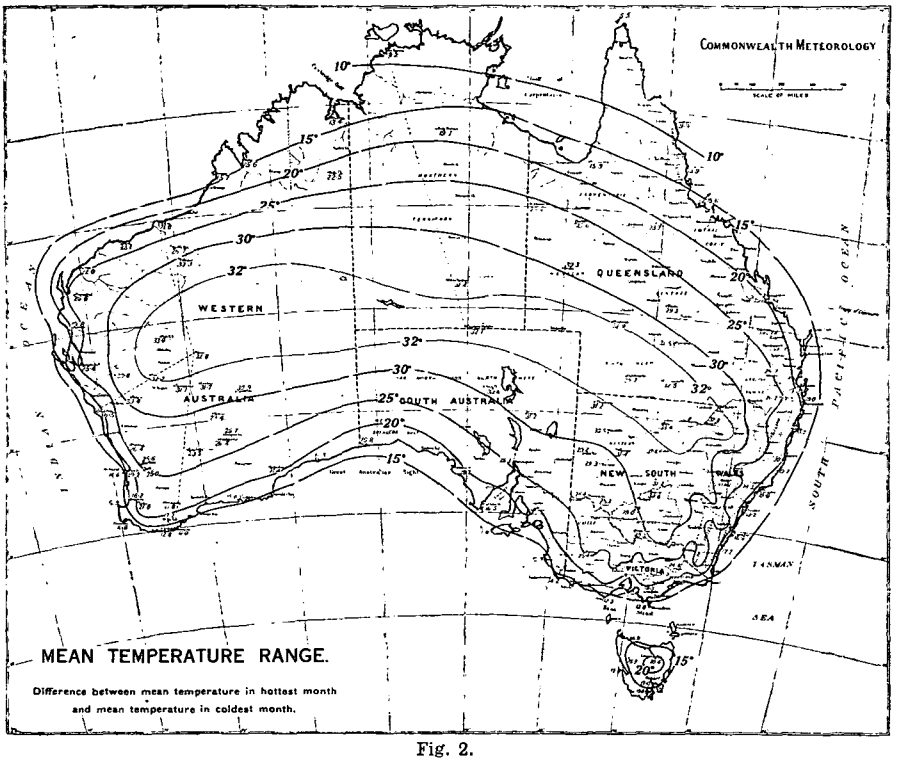


Fig. 2.

RAIN RELIABILITY.

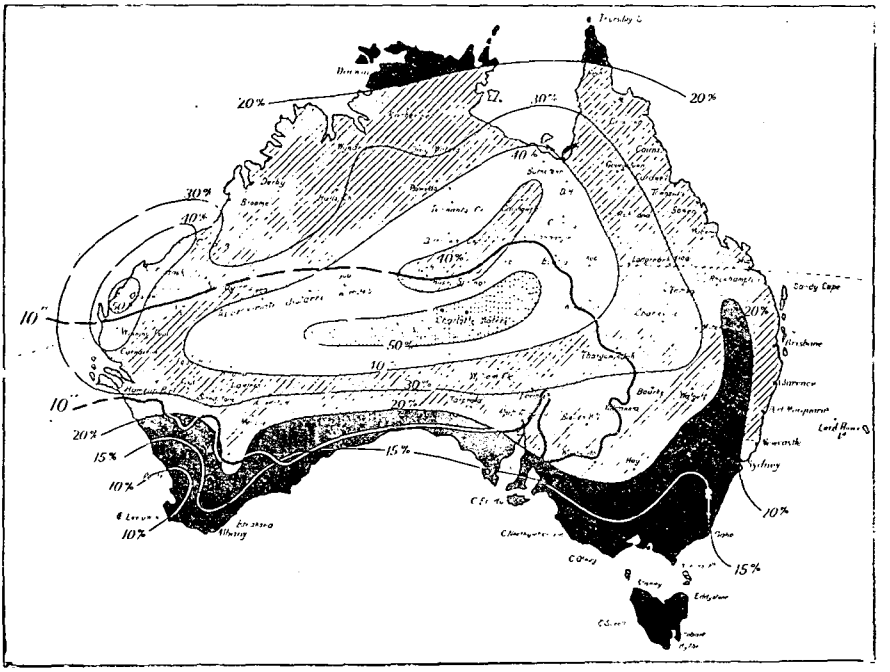


Fig. 4.

Mean Percentage Variations from annual normal years, 1891-1910.
Regions with most reliable rainfall are shewn black.

ECONOMIC REGIONS OF AUSTRALIA BASED ON VARIATIONS IN THE AMOUNT, SEASON, UNIFORMITY AND RELIABILITY OF THE RAINFALL.

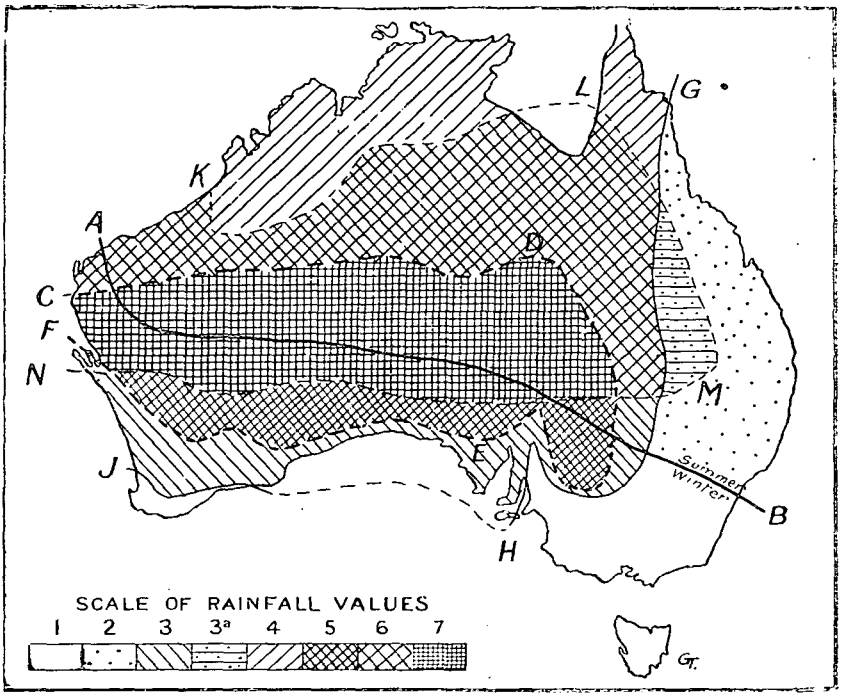


Fig. 5.

The grades are described in Table 10, page 97.

HYTHERGRAPHS FOR TROPICAL AUSTRALIA.

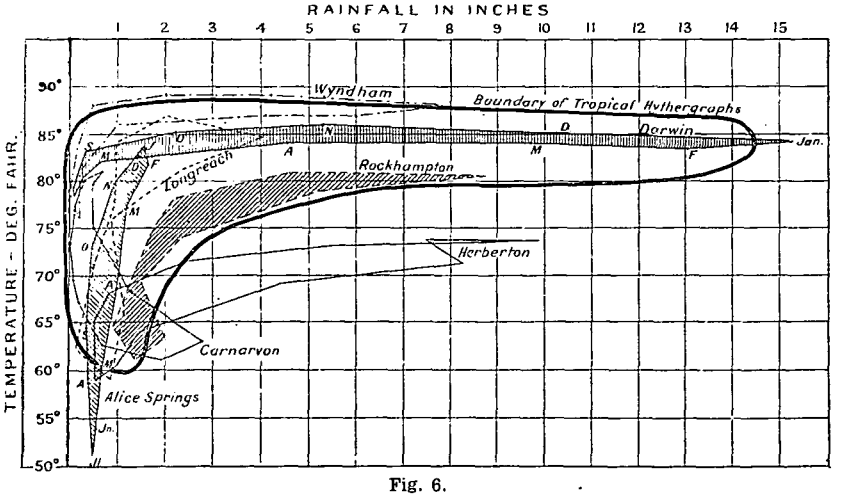


Fig. 6.

The heavy black line includes almost all tropical localities.

HYTHERGRAPHS FOR TROPICAL AREAS GROWING WHEAT, RICE, COTTON, TEA AND COFFEE.

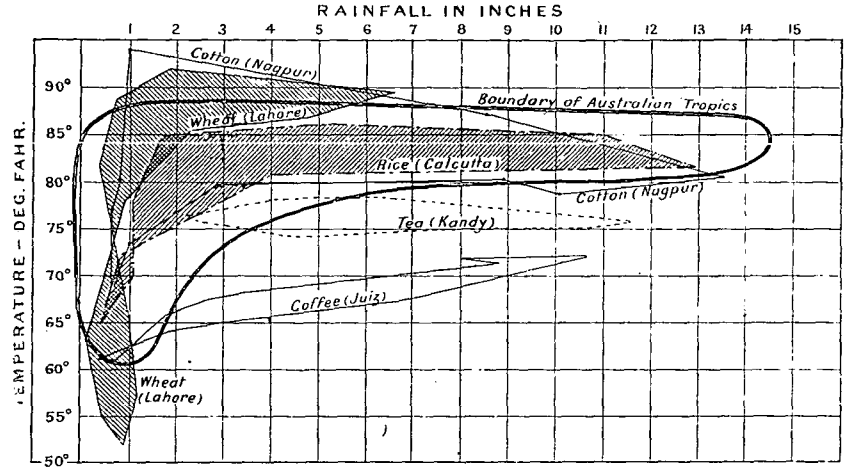


Fig. 7.

The heavy black line shews the limits of almost all the tropical localities in Australia.

ISOPLETHS OF DISCOMFORT.

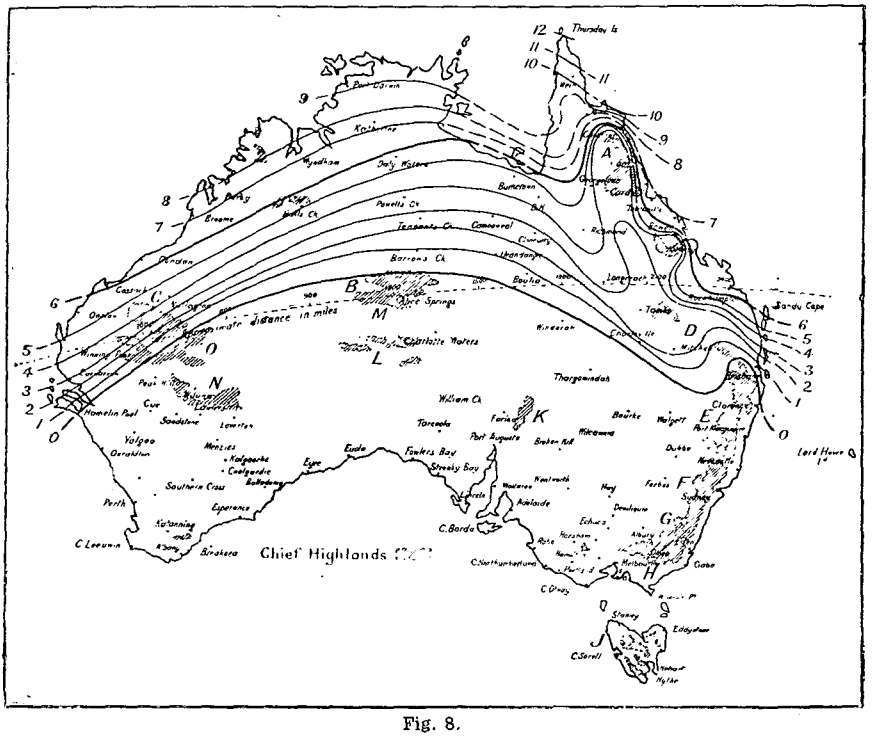
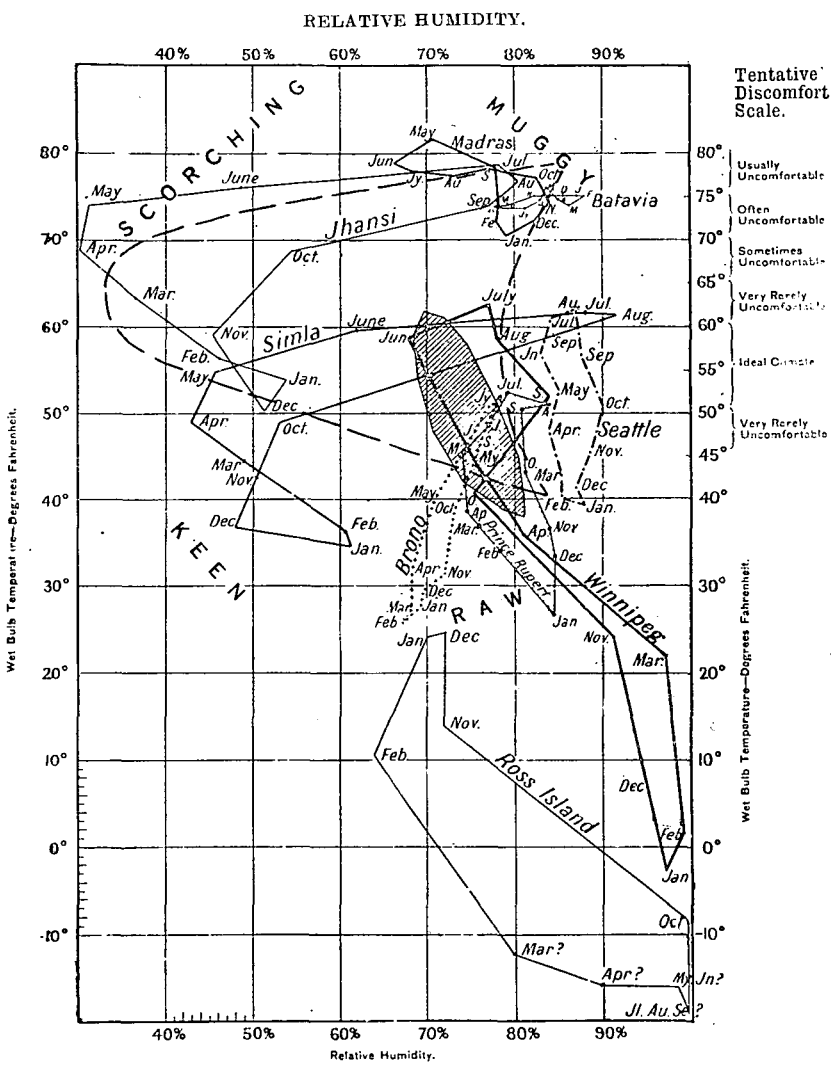


Fig. 8.

The figures shew the number of months with an average wet bulb over 70° F. The shaded areas are over 2000 feet above sea level.

CHARACTERISTIC CLIMOGRAPHS ILLUSTRATING IMPORTANT CLIMATIC TYPES.



NOTE.—The shaded figure is the composite white race climograph based on twelve typical cities.

Fig 9

TYPICAL CLIMOGRAPHS FOR AUSTRALIA.

The empirical boundary between arid and moist regions is given. (London and Berlin added for comparison.)

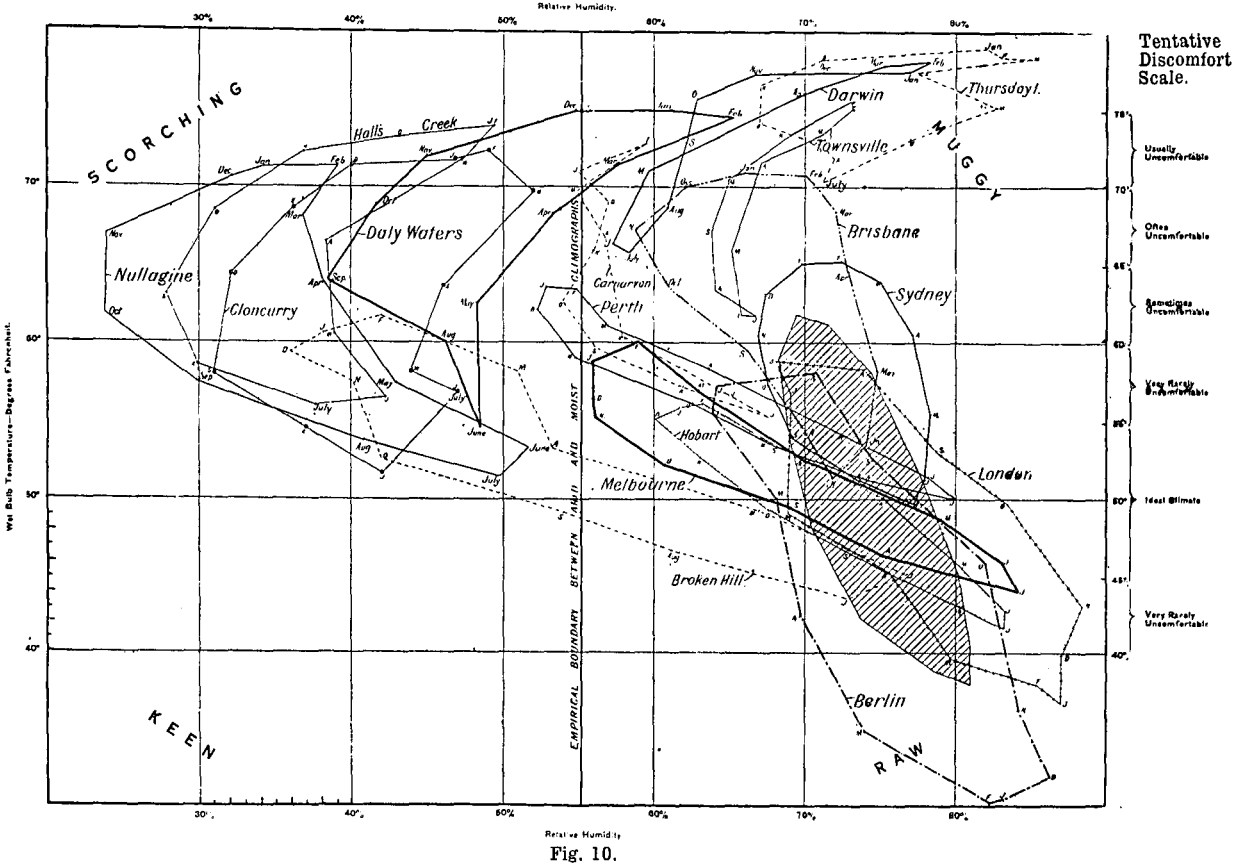


Fig. 10.

NOTE.—The shaded figure is the composite white race climograph based on twelve typical cities.

In the same way the northern rains are largely due to the tropical cyclones which hover over northern Australia when the sun is overhead in the tropics, i.e. in summer. The northern summer rain-controls extend, however, barely as far south as Oodnadatta, South Australia, while the southern winter rain-controls normally extend north approximately to Farina, South Australia. Hence the great arid region of Australia is in the broad belt only occasionally favoured by either of these beneficial controls. This arid area extends from North-west Cape to Broken Hill, and includes thirty-seven per cent. of the area of the continent.

The dominating winds in this arid stretch have an easterly component, and, towards the north, merge of course into the permanent South-east Trade Winds. In the interior and in the western lands it is typically a drying wind, but in the east it blows from sea to land, and contributes largely to the heavier eastern rainfall. At the same time there is a special series of tropical storms which swing down the east coast from the north in autumn and winter, and give its definite character to that region.

Hence, speaking generally, there are four major rainfall regions. The summer rain region in the north, the winter rain region in the south, the uniform rain region in the east, and the arid region in the centre and middle west.

The uniform region may be defined as that which receives over one inch per month through eight months in the year. This uniform portion includes all east of a line from Cairns south to Wentworth, and thence west to Adelaide, and Bunbury, Western Australia. This region also includes almost all the timber areas in Australia, which are largely determined by the uniformity of the rain. Along these coasts, moreover, are the only regions where the evaporation is balanced by the rainfall. Hence the heavy tropical rains of the Northern Territory do not produce timber forests, for the six months' drought in winter prevents the growth of true tropical forests.

Fig. 5 shews how the rainfall varies in amount in season, in uniformity, and in reliability. Thus, considering rainfall alone, one can usefully distinguish seven regions, which may be arranged in order of their value for settlement somewhat as in the following table :—

TABLE X.—MAJOR RAINFALL REGIONS.

Class.	Sub-class.	Chief Localities.	Chief Products.
I. Uniform ...	1. With winter maximum	Riverina, Victoria. Tasmania, Albany	Timber, dairies, farming, sheep, wheat, vines.
,, ...	2. With summer maximum	Eastern Queensland, North-east of New South Wales*	Farms, sugar, sheep, cattle; also timber, dairies and sugar on coast.
II. Seasonal, but reliable	3. Moderate winter type	Swanland, W. Australia† ...	Wheat, sheep, vines.
,,	4. Summer type ...	Kimberley, W. Australia and Coastlands, N. Territory	Cattle.
,,	5. Arid winter type ...	Coolgardie to Broken Hill ...	Sheep.
III. Erratic ...	6. Summer only ...	Pilbarra, W. Australia, Macdonnells, N.Territory, Western Queensland	Sheep and Cattle.
,, ...	7. Arid	Central W. Australia and Inland S. Australia	Relatively empty, a few sheep and cattle stations only.‡

* Type 3a (*on* Fig. 5) *is too erratic to be classed with type* 2. † The temperate and well-watered south-west corner of Western Australia. ‡ Mining is ignored.

9. **Climate and Production.**—The control of wheat and of cattle and sheep-raising by rainfall and temperature is considered very fully in Meteorological Bulletin No. 11,* to which the reader is referred. On the maps in that bulletin it is shewn that cattle are chiefly raised in regions having more than twenty inches of rainfall per annum. Temperature has little effect. Sheep are very largely contained between the twenty and thirty-inch isohyets, though they are numerous between the ten and forty-inch isohyets. They do not extend so far north as the cattle; the hinterland of Broome, Western Australia, being the most northern of the important sheep areas. Wheat is grown almost entirely between the ten and twenty-inch isohyet. It is limited by temperature in the north, for very little is grown north of Nanango, in south-east Queensland, which has an average annual temperature of about 70° F.

10. **Potential Production in the Tropics.**—The two chief controls governing crops are, of course, temperature and rainfall, and the rain must stimulate growth at the the proper season of the year. It is comparatively simple to express graphically the climatic conditions which are highly favourable for such crops as cotton, tea, coffee, rubber, etc. Such graphs have been named *hythergraphs*† by the writer of this article, and they are illustrated in Figs. 6 and 7.

For each locality a table of the twelve average monthly temperatures and rainfalls is consulted. These twelve points are plotted on a chart with the proper co-ordinates. Thus, each locality is represented by a twelve-sided polygon—the hythergraph—which accurately represents the march of temperature and rainfall throughout the year. In Fig. 6 are graphs for tropical Australian towns—Wyndham, Darwin, Rockhampton, Longreach, Carnarvon, and Alice Springs. All these fit within a slipper-shaped boundary, which represents the general range of climate in Northern Australia. Herberton, on the elevated Atherton Plateau, is seen to be quite exceptional in its climate.

The application of this graph is seen in Fig. 7. Here are plotted the graphs for such places as Lahore (which is a very important district for summer wheat); Calcutta, a typical rice region; Nagpur, famous for cotton, etc., etc. It will be seen that all these graphs can be closely paralleled on the north coast of Australia (see Fig. 6). No account is taken of soils (which lie outside the writer's province), but it may be assumed that there are many acres of suitable soil near the permanent rivers flowing to the north coast.

Such crops as tea and coffee need cooler regions, and there are few such in the tropics. It will be seen that the hythergraph for Herberton indicates that the wetter portion of the Atherton Plateau is very suitable for these crops. Many experimental plots have, of course, been devoted to new products on various research farms in Australia. This climatological study will, however, support their introduction on a larger scale.

11. **Wet Bulb Temperatures and Comfort.**—It is generally accepted by physiologists that the best available instrument for testing the suitability of a region as regards habitability is the wet bulb thermometer. Professor J. W. Gregory quotes 78° F. wet bulb as a limit—"above which continuous hard work becomes impracticable." Unfortunately for Australia 78° F. wet bulb is quite common in summer along our northern coast, but this statement (by a strong supporter of tropical white settlement) will free the following deductions from a charge of exaggeration.

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* "The Climatic Control of Production," by Griffith Taylor, 1913.

† *Hyetos*, rain; and *therme*, heat. See "The Australian Environment."

For reasons which are elaborated in Meteorological Bulletin No. 14,* 70° F (wet bulb) has been adopted as the limit of comfort for our race. This means that when the average wet bulb remains above 70° F. day after day for a long period, conditions are not favourable for close white settlement. An open-air active occupation such as stock-riding has little to fear; but strenuous field labour, sedentary indoor life, and especially domestic work and the care of young children, cannot be carried on under favourable conditions at present with high wet bulb temperatures of this order.

It is well known that February is usually the most oppressive month both in Sydney and Melbourne. The average wet bulb temperatures for this month are, however, only 65° F. and 60° F. respectively, while at Melbourne the extreme reading for any day in the year rarely exceeds 75° F.

Brisbane has two months with an average wet bulb over 70° F., and conditions become continuously less attractive as one journeys up the coast. At Mackay such high wet bulbs obtain for six months in the year; at Cooktown for ten, and at Thursday Island all the year round. These isopleths are plotted on Fig. 8. It will be noticed that it is precisely the low-lying river alluvials of the north which are adversely affected. Here irrigation may ultimately be possible, for there are many fine rivers running into the northern seas. But it is doubtful if a white farming community will settle in these agricultural areas for very many years.†

12. **Comparative Climatology and the Climograph.**—Just as heat and moisture determine the well-being of plant life, so do they control the comfort of the human race. But in place of the dry bulb and rainfall, the wet bulb and humidity indicate more directly the effect on man's feelings. Indeed wet bulb temperatures have been termed "sensible" temperatures for this reason. Humidity is a better factor than rainfall—for the average rainfall at a place often remains at zero for many months of the year, while the humidity rarely falls below 40 per cent., and shews the sequence of climatic changes much more clearly.

A graphical representation, akin to the hythergraph for crops, can therefore be drawn from the twelve monthly means of humidity and wet bulb at the required locality. This the writer has named the *climograph*, and it is being accepted generally as giving a clear picture of the climatic changes. (See Bulletin 14.)

In Fig. 9 are shown types of all the chief climates of the world, while at the side is a tentative scale of discomfort depending on the wet bulb readings alone.

As a criterion enabling one to judge if a locality is well suited for close white settlement, a composite climograph is given, based on averages from twelve centres of Anglo-Saxon settlement. This is the cigar-shaped climograph which is shaded in Fig. 9.

Unhealthy regions near the Equator with a uniformly muggy climate are represented by Madras and Batavia. Scorching dry regions—with, however, monsoonal rains in midsummer—are illustrated by Jhansi in Central India. Simla shows one of the keen winter types, though it is also affected by the monsoons in summer. London (see Fig. 9) agrees almost exactly with the type white climograph. Seattle, United States of America, is similar, but wetter. Bronno, near Trondhjem, and Prince Rupert, British Columbia, illustrate raw conditions. Winnipeg and Ross Island, Antarctica, extend far below the temperatures of normal white settlement.

Australian localities have a fairly wide range, as will have been gathered from the first section of this article. There are no "keen" or "raw" climates, but "scorching" and "muggy" types are but too well represented. The more important places are all given

* "The Control of Settlement by Humidity and Temperature," by Griffith Taylor, Melbourne. 1916. † *Vide* "Settlement in the Tropics," by Griffith Taylor. Royal Geographical Society of Queensland, 1918.

on Fig. 10. The cluster of climographs covers an area curiously resembling an arrow-head, and this outline is inserted on the general chart, Fig. 9. (For other continents the climographs would cover a much larger area of the chart.)

The cooler localities in Fig. 10 have the major axes of their climographs running north-west—which means dry summers and wet winters. The hotter localities have the major axis running north-east—which means they are in the monsoon region, with wet summers. The inland localities have low humidity, and so appear at the left of the chart, usually as crescents, which fact indicates that they have a little winter rain and a little summer rain. The climographs for east coast localities (Sydney, Brisbane, etc.) are much less elongated, which implies that spring differs from autumn more than in the other portions of Australia; in fact, the special autumn rainfall is indicated by the high humidity, as we should expect.

The Tentative Scale of Discomfort at the side of the chart will enable the reader to see the conditions in any month at any of the localities at a glance. He can also compare the localities *inter se*; and by reference to the original memoir (Bulletin 14, where seventy climographs are charted) with most other regions of the world.

13. **Settlement in the Tropics.**—The chief object of this article is to focus attention on the climatic difficulties which hinder settlement in the unoccupied regions of Australia. Space does not permit of the insertion of further illustrative climographs, but the following table seems to indicate that our northern lands are not well suited for *close* white settlement. In the table the foreign homoclime (similar region) appears in each case at the right of the Australian locality. (See also Fig. 1.)

TABLE XI.—TROPICAL AUSTRALIAN HOMOCLIMES.

AUSTRALIAN LOCALITY AND A FOREIGN HOMOCLIME.													
Locality.	Temperature.			Rainfall.			Locality.	Temperature.			Rainfall.		
	Average.	Hottest Month.	Coldest Month.	Average.	Wettest Month.	Driest Month.		Average.	Hottest Month.	Coldest Month.	Average.	Wettest Month.	Driest Month.
	°F.	°F.	°F.	Inch.	Inch.	Inch.		°F.	°F.	°F.	Inch.	Inch.	Inch.
Broome ...	79.8	85.9	70.3	23	6	0	Banana, R. Congo	77.9	81.5	72.5	29	6	0
Nullagine	79.8	85.9	70.3	23	3	0	Colima, S.W.Mexico	76.1	80.0	69.6	34	7	0
Carnarvon	71.0	80.0	60.0	9	3	0	Olukonda, S.W. Africa	72.0	77.0	51.0	19	5	0
Wiluna ...	70.0	85.0	52.0	10	2	0	Windhoek, S.W. Africa	67.0	74.0	56.0	15	4	0
Darwin ...	83.0	84.0	77.0	62	15	0	Cuttack, E. of India	80.0	87.0	70.0	55	12	0
Daly Waters	80.0	87.0	69.0	27	6	0	Quixeramobim, Brazil	81.0	83.0	79.0	27	6	0
Alice Springs	70.0	84.0	53.0	11	2	0	Biskra, Algeria	69.0	89.0	51.0	10	1	0
Townsville	78.0	82.0	66.0	49	11	0	Calcutta	78.0	82.0	65.0	60	12	0
Wyndham	84.5	88.3	76.2	27	8	0	Tinnevelly	84.3	89.5	78.5	28	9	0

Assuming that these and similar parallels are correct, it will be seen that the analogous regions (homoclimes) for Darwin are settled by Siamese, Indians and Bantu Blacks, and in Northern Brazil by half-caste Portuguese. Wyndham (as stated earlier) has for homoclime only the extreme tip of India. Broome's homoclime is inhabited by Bantu, and Townsville's (Rio de Janeiro) settled by the Portuguese.

Only in the inland country like that around Wiluna or Daly Waters, is there a h omoclime even sparsely settled by North Europeans. This is the recently conquered German territory of South-west Africa.

In Eastern Brazil is a most interesting series of settlements; but the Germans have settled in the homoclime of Grafton; the Italians in Brazilian "Brisbane," and only the Spanish immigrants touch even the cooler tropical regions.

This brief but comprehensive climatological study shews that Australia is ahead in tropical settlement. Her white sugar-growers around Cairns and Mourilyan are the advance guard of the white farmer in the tropics.

Limitations of space permit merely an allusion to one great asset in Australian northern lands—their freedom from yellow fever, and comparative immunity from beri-beri and malaria. There seems good reason to hope that the two latter will eventually disappear.

What then is indicated as regards the immediate future of the empty northern lands of Australia? The country is essentially a pastoral one—it is not an agricultural region. Apart from questions of labour and market, the lowlands west of Cooktown do not appear to be suitable for white farming at present.

A consideration of progress in Algeria and similar regions indicates that conditions in the Australian tropics may become more acceptable to white settlers in the future. In four or five generations it is possible that the native-born may become thoroughly acclimatised in the sub-tropical areas, and will then gradually spread in considerable numbers into the hotter and more humid zones to the north.