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THE SCOTTISH GEOGRAPHICAL MAGAZINE.

RAINFALL IN AUSTRALIA.

VALUE OF RAIN AND IRRIGATION.

BY J. T. WILLS.

RAINFALL statistics and maps are little heeded by the British public, as a rule, for want of a vivid appreciation of the extreme value, in dry countries, of every inch of rain.

I have, therefore, appended to the two maps of Australian rainfall, some facts and considerations from which, in a rough way, and under given climatic conditions, we may trace the limits of agriculture, and estimate the pecuniary value of rain and of irrigation water.

In South Australia there seems to be a close and direct relation between rainfall and wheat-yield, which is very interesting, and which does not appear to have been hitherto noticed or discussed.

The new and important departure now being taken in Victoria in state-controlled irrigation (which should be closely watched by investors and promoters of emigration in this country) gives a practical interest to the subject of water values; as do the vain efforts of New South Wales to plant agricultural settlers in districts where they cannot prosper, to the question of the limits of agricultural settlement.

The first map shows the annual rainfall in Australia. The South Australian records are the longest and most complete, but no returns later than 1882 are to be found in this country. The colony has had bad seasons since, and apparently wishes to conceal the fact by not publishing returns. Her agricultural statistics, too, have just been discontinued, because they were such melancholy reading. In the other colonies I had to use the tables of monthly and yearly rainfall for the ten several years 1871-1880 throughout Australia (in millimètres),

published by Raulin in the *Bulletin of the French Meteorological Society*, 1884, as Victoria sends no annual returns (that I can find) to London, but only monthly sheets, and New South Wales, though prodigal of annual, is most chary of monthly totals. In the interior slope, or Darling and Murray basin, in New South Wales and Queensland, the *annual* rainfall lines are copied from Mr Gipps'¹ rainfall map of that basin, which appears with his article on the irrigating capacity of the New South Wales rivers in the second number of the *Australasian Geographical Society's Journal* for 1886. His map is drawn from the averages of all observations made there up to the end of 1883. The course of his isopluiose lines evidently follows the contour lines, which are not to be found in any map in this country, but with which Mr. Gipps is familiar. The remaining lines in Queensland are taken from the Queensland rainfall map in the Colonial Exhibition, and represent the averages of only seven years, 1878-84. As for the previous returns,—these are scanty and of doubtful value.

In Victoria, in the Murray Basin, I have had to correct Mr. Gipps' lines. Not being concerned with the water supply there, he had drawn his lines less carefully.

On the coast slope in New South Wales, the averages are made up to the end of 1883. In Victoria (coast slope) and in West Australia they are only for 1871-80 (from Raulin). In Tasmania the rainfall shown is that of the one year 1885. I had hoped to get uniform and complete returns everywhere for fourteen years, 1871-84; but the colonial agencies simply do not keep, and do not supply other libraries with, the necessary data. The map is therefore provisional. The period 1871-80 alone would not have correctly represented the average climate. In East Australia generally, especially in New South Wales, that period was more rainy than the average. The drought that followed in 1881-85 was by no means unprecedented, and should be expected to occur again.

Annual rainfall is a fair *primâ facie* guide to the pastoral capacity of a country. Grass benefits by rain at any season (provided that enormous deluges do not come, as they often do in Australia, in a single day), and the more even the distribution is throughout the year the better. The cultivator, on the other hand, requires rain for about half the year, and is scarcely benefited by rain in the other half. This is especially true of grain crops and vineyards.

The second map is prepared, therefore, with reference to agriculture, and, especially as far north as Toowoomba, Queensland, with reference to the cultivation of wheat, which is the limit crop where rainfall is slight. Ten inches rainfall in the winter half of the year is about the limit of wheat culture, and of agriculture generally on fairly good average soils. Raulin's tables for the years 1871-80 have been taken, and the returns of the *four years* 1881-84 have been added wherever possible. North

¹ The Government Surveyor of New South Wales.

of Toowoomba these rains are insufficient for wheat or any other usual winter crop.

The wet season in Queensland is the summer. The limit of 20 inches of summer rains in the wettest six months is laid down for the same period, 1871-84. It probably marks the limit of maize culture.

The lines of 20, 25, 30 inches annual rainfall in the Darling basin, according to Mr. Gipps, and of 30 and 40 in Queensland (for the years 1878-84), the figures indicating the annual¹ rainfall of districts on the coast slope of New South Wales, are also shown on the map, these annual rainfall lines being dotted. The addition of subsequent returns would bring Mr. Gipps' lines a little nearer to the coast, and would reduce the Victorian averages. In South Australia, "Goyder's line" is marked. It was laid down as a guide and limit to farmers, and its correctness as an indication of the limit of profitable regular wheat culture has been pretty well demonstrated by sad experience. It nearly corresponds to the limit of 15 inches rain in the year, or of 10 in the winter half-year.² No ordinary map of Australia should fail, though all do, to mark it.

THE VALUE OF RAIN.—Land without rain is worth nothing, and land in an Australian climate with less than 10 inches a year is worth next to nothing. Rain-water without land, if it can be stored in a reservoir and sent along a canal, is worth a great deal. In Spain, for instance, flat, unirrigated, but irrigable land, in the plains of Valencia or Murcia (which are on the Mediterranean coast), and with soils of first-rate quality, is worth £20 an acre. These lands have an annual rainfall of some 18 inches, and can obtain irrigation water generally by paying for it. Uplands in Castile, with a rainfall of 10 inches a year, are hardly worth anything at all. But if I owned a canalised river and reservoir in Murcia (the Lorca reservoir, for instance, where water is sold every day by auction), I would rather have an extra square league of bare rock added to the area, whose rainfall filled my river (provided a full 10 inches of rainfall ran off the rock into the river annually), than two square leagues of this good bottom land worth £20 an acre, with its 18 inches of annual rainfall that sank in or evaporated where it fell. The rock would be worth more.

Moreover, in a climate like that of Australia, while land with 10 inches rainfall is almost valueless, land with 20 inches is not half so valuable as similar land with 30. Of course, in speaking colloquially, as I do here, of differences in "rainfall," the usual concomitant differences in humidity, rate of evaporation, and the like, are implied as well. I assume that the

¹ Average of all observations, up to the end of 1883. Stations in one district are grouped, and the mean rainfall of the group is taken. These figures appear on the map of rainfall appended to the New South Wales *Report* on the state of the Crown lands.

² The rains decrease with the elevation on both sides of the range of hills, and most rapidly on the north-east. See Trollope's *Australia* for "Goyder's line."

rainfall of the surrounding district is similarly raised, else its dry air and heat would parch the solitary favoured spot.

Compare first the increase of *pastoral* capacity with the increase of rainfall in the following wide areas.

1. South Australia has $6\frac{1}{2}$ million sheep, and 500,000 square miles leased for pasture, the average rate therefore is 13 sheep to the mile only;¹ deducting the sheep on the freehold lands, and the crown leaseholds intermixed with them (a deduction of less than 2 per cent. of the total area), it is only some 8 or 9 to the mile on the remainder, where the rainfall averages some 8 or 10 inches. A great part seems to be leased at half-a-crown a square mile, with compensation for improvements for fourteen years, or for twenty-eight years without compensation² at an increased rent. Of the unleased land in the interior of the colony, the great part is desert and valueless, as is also almost the whole of West Australia (and indeed of the United States and Central Asia) below the 10-inch line.

2. In New South Wales, the west half (55 per cent.) of the colony, west of the longitude of Forbes, and north and east of the Lachlan, carried in 1881 just 96 sheep to the square mile. The rainfall averaged for some years previous to 1882, 13 inches.³ The surveyor estimated in 1882 that if improved to its full capacity⁴ (so that drinking water might be had wherever required), this land could or might carry 120 to 130 sheep to the mile. It is, however, clear that if seasons like the last three, 1883-5, are to recur—as recur they will—this estimate is very high. Half the sheep there have died for want of grass.

3. The "good lands" of the interior of New South Wales, that carry a sheep to the acre, have a rainfall of 19 or 20 inches, and a first-rate soil.

4. In the state of Buenos Ayres,⁵ which I take as a wide, flat, uniform, open country, with the same mean temperature as that last-mentioned, the numerical density or distribution of sheep and cattle, is recorded in the census of 1881, and the numbers returned are supposed to be much below the reality. It appears by the census that the twenty-two counties lying north of the Salado and west of the capital, where there is a

¹ The *Government Handbook* says, at p. 155, the carrying capacity of pasture land in South Australia varies from 40 to 640 sheep to the mile, in its *natural*—i.e. unimproved—state (*sic*!).

² And with every prospect of having greater security for improvements given by forthcoming legislation.

³ See a kind of rainfall map appended to the Report of Messrs. Ranken and Morris on the state of the public lands of New South Wales. This is the Report on which the new land laws of 1885 were based. It is printed in vol. ii. of the *Votes and Proceedings of New South Wales* for 1883, and is a work of great thoroughness and geographical value.

⁴ P. 134 of Ranken and Morris's Report. Later and detailed returns of the estimated capacity of each run in the western districts, when fully improved, made in order to see where Crown rents could be raised, are also given in *Votes and Proceedings*, 1883-4, vol. iii. p. 265. They show a very small margin of improvability indeed.

⁵ Buenos Ayres has the same mean temperature as Forbes and Dubbo on the plains, Central New South Wales, long. 148½ E.

rainfall of about 34 inches (and where the finer grasses which therefore can be made to grow there have been fairly generally introduced), are stocked at the rate of 2630 sheep to the square mile. Cattle and horses are included in this figure, reckoned as equivalent to so many sheep.¹

5. *Under irrigation*, the Californians affirm that an acre of lucerne will keep twenty sheep, if it is cut for them. It will certainly keep over ten.² The *amount* of irrigation and rain is not more than 60 or 100 inches a year for the 10 or 20 sheep respectively, and is probably more like 53 and 84 inches.

These figures show progressive rates of increase, thus :—

District.	Rain.	Sheep per mile.	Increased capacity for every inch of rain, etc., added.
1. South Australia, .	Say, first 8-10 inches.	8-9?	about 1 sheep p. mile.
2. New South Wales, .	9 + 4 "	96	" 22 " ³
3. " " " "	9 + 4 + 7 "	640	" 70 " ⁴
4. Buenos Ayres, .	9 + 4 + 7 + 14 "	2630	" 140 " ⁵
5. Californian lucerne, } irrigated, .	34 + 26? "	12,800	{ over 145, ⁶ and probably more like 200.
	34 + 66? "		

These figures show, as far as their looseness permits, a progressive increase, thus :—

District.	Pastoral Capacity Increases for every Extra Inch of Rainfall at the rate in Sheep per Square Mile.
1	Of 1 sheep for every inch of rain over absolute desert.
2	" 22 " " " over No. 1.
3	" 70 " " " over No. 2.
4	" 140 " " " over No. 3.†
5 (a)	" 145-200? " " " over No. 4.
5 (b)	" 145-200? " " " over No. 4.
5 (b) Is a case of 20 sheep fed on an acre of lucerne which gets 84 to 100 inches of water a year.	

This progression is what one would expect. In dry districts the

¹ See p. lviii. of the Census, which assumes that 1 cow=8 sheep, and a horse=6. A not inconsiderable part of the area, not deducted, is under cultivation. The total area of this solid block of counties is 12,272 square miles : sheep 20·43 millions, cattle 0·89, horses 0·47 millions. It is supposed the live stock figures are 15 per cent. below the reality, taking the State as a whole. There is also a large area with 1550 to 2070 sheep units per square mile, with a less rainfall, but capable of being better grassed than at present. The increase of stock from 1881 to 1882 was supposed to be 10 per cent. on the total numbers in the State.

² *Report on Irrigation in America; Victoria Votes and Proceedings*, 1884, vol. ii. ; and Mr. Gipps' paper to Royal Society of New South Wales, p. 326 : "There are 1000 acres of flat, sandy land in the San Joaquin valley, which in their natural state would have fed one sheep to the acre ; irrigated and growing alfalfa (lucerne), it now feeds twenty to the acre."

³ A very few horned cattle are also kept in this part.

⁴ If fully improved. ⁵ Not the full actual numbers.

⁶ Suppose an acre of lucerne required 60 inches of water and rain in order to feed 10 sheep, it would carry 145 extra sheep per inch of excess over No. 4.

evaporation is enormous,¹ and even at Adelaide an inch of rain in the summer "only washes the dust off the leaves." A small annual rainfall never soaks in.

So far for pasturage. Let us next take wheat. Here we have some very reliable data from South Australia. Mr. Todd has compared the variations there in mean rainfall from one year to another with those of the annual wheat-yields. The agricultural area is small, compact, uniform in climate, soil, and general character, and a great part of it is sown with wheat, and very little else is grown at all.² It has been thickly covered with rain-gauges ever since 1861, under Mr. Todd's directions, and he has chosen carefully, before making his tables, those rain-gauges which he considers together give or correctly represent the mean fall of rain on the areas under wheat. Moreover, as new wheat districts have sprung up fresh rain-gauge stations have followed them. Some of those chosen are only nine years old, because they have "followed" the wheat crops. There is no other crop, indeed, to follow. Until 1880, the area of cultivation whose yield is returned did not to any great extent overstep the districts whose rain is measured. In 1880-82 it did. Till then, gradual improvements in cultivation seem to have counterbalanced the partial exhaustion of the soil in the older districts. The conditions therefore are favourable for an induction.

Comparing the mean rain of the winter *six*³ months with the harvest yields, and grouping the years in sixes, to eliminate to some extent the variation from one single year to another of other conditions affecting the harvest, it appears that the difference in bushels per acre of average yield is almost exactly the same as the difference in inches of rain: 18 inches give 12 bushels, 15 give 9, and 12 give 6. In fact, the difference between the number of bushels and inches is constant, and is just about 6. The tables so arranged and averaged are as follows:—

Averages of groups of years.	Rain. Inches.	Yield. Bushels.	Inches minus bushels.
7 best years (11½ bushels and over), .	18·47	12·43	6·04
5 next best years (8 to 11 bushels), .	15·28	10·02	5·26
6 bad years (5 to 8 bushels), .	13·55	6·61	6·92
Total 18 years, 1861-1879, excluding 1867,	15·76	9·69	6·07
3 years (1880-82) when wheat was grown beyond the rain-gauges in drier parts,	13·22	4·58	8·64

¹ Chapter by Mr. Todd in Hareus's book on South Australia. At Bourke the annual evaporation is 85 inches.

² The southern part had been extensively cropped long before 1861.

³ Excluding the year 1867, when red rust, due to heavy rains in very hot weather just before harvest, almost wholly destroyed the yield. Mr. Todd has finally fixed upon a six-month period in preference to seven or less. He leaves us to draw our conclusions and frame our own equation from inspection.

An *extra inch* of rain in the season on the little area of South Australian wheat lands—some two million acres—would give it an additional fee-simple value of *ten million pounds*, if wheat at 4s. a bushel or equivalent crops were grown. If the whole area inside Goyder's line—some 8000 square miles—profited equally by the same increase of rain, it would be worth a million a year more than it is now. The rental of the whole present herbage in the central two-thirds or three-fourths of Australia, outside Goyder's line, where there is less than twenty inches of rain, if it was fixed at 6d. per sheep, which is the rate just fixed by the Victorian Government in leasing the north-west quarter of Victoria,¹ would not be worth ² more than this extra inch inside Goyder's line.

The average distribution through the six winter months of the rain, from which these results are obtained, is as follows :—2·99, 2·80, 3·01, 2·57, 2·15, 1·87 inches, in the several months May to October ; the total fall in the hot season being just over 6, of which 1½ falls in April. The mean winter temperature (June-August) at Adelaide is 53·1° ; that of the year is 63°. Wheat is sown about the first of June, and is harvested late in November or in December. No doubt, under very favourable conditions, every inch would go a good deal further in the production of wheat. Wheat likes a cool, moist season for sprouting and tillering,³ and would give greater yields if May, June, and July were colder, and had a greater proportion of the total rain of the season. In New South Wales, however, along the 10-inch winter rainfall line, the temperature is rather higher than in South Australia. Farther east, on the watershed and high grounds at 2000 feet above the sea, of course it is cooler. Towards and beyond the Queensland border, wheat culture is almost entirely confined to such altitudes. In 1881,⁴ all the unruined wheat in Queensland, except some 200 acres, was reaped inside the two small police districts of Warwick and Toowoomba, close to the watershed ; the acreages where the crop was spoiled by rust, both inside and outside

¹ In the centre of Victoria, where meat as well as wool can be marketed, rates are higher.

² Could it carry 40 million sheep ? In 1881-83 there were in Queensland on the west side of the dividing ridge 10 millions ; in the west and central two-thirds of New South Wales about 20 ; in South Australia 6½ ; and in West Australia 1½ millions—a large part of the sheep in these two last colonies being without this area.

³ "The ideal climate for wheat is one with a long or rather wet winter, with but little or no frost, prolonged into a cool or rather wet spring, which gradually fades into a warmer summer, the weather growing gradually drier as it grows warmer, with comparatively light rains after the blossoming of the crop, just enough to bring the grain to maturity, and abundant sunshine and rather dry air towards harvest, but without dry or scorching winds till the grain is fully ripe, and then dry hot rainless weather till it is harvested. . . . A warm dry rapidly growing spring diminishes the yield, as the branching or tillering must take place before the plant gets far above the surface, or else it does not occur at all."—Special Report on Cereal Production, by Prof. W. H. Brewer, United States Tenth Census (1881), vol. iii. p. 63, of that Report. "These conditions," he adds, "are more nearly realised in the better years in Southern California than anywhere else in the States. The better years of course mean the wettest. In point of spring temperature, if not in distribution of rain, Victoria would be rather better than South Australia."

⁴ I quoted this fact in a previous article upon Australian Government publications.

those districts, being somewhat greater than what was left clean. It is the bursting of the summer rains before the crop is ripe for harvest that causes rust; to sow early so as to avoid this, is to sow whilst it is very hot. The wheat-grower is on the horns of a dilemma.

Wherever it is true that on the average $6+x$ inches of rain in the six months are required to produce x bushels an acre, it will hardly pay expenses to grow wheat even at a price of 5s. a bushel on the farm, unless there is 10 inches of winter rainfall; for the cheapest style of wheat-farming in the world on big machine-using farms costs just £1 an acre,¹ all just allowances included. I therefore suggest that the 10-inch line on the second map is not far from the limit of wheat or other cultivation.

Maize culture will probably find its limit in a climate such as that of inland Queensland, where there is 20 inches of rain in the six wet summer months. The Signal Service Department in the United States has just begun a course of comparisons to see how far the yield of maize (and other staple American crops) varies with the rainfall of the season. The only set of tables already published by them are, however, introductory, tentative, and inconclusive.² Parts of Texas resemble in climate Queensland, Natal, and Zululand, and parts of California, the southern Australian coasts; but, as a rule, American climates and Australian are not comparable.

The limit of the heavier rainfalls (40, 50, 60 inches a year) are of interest as affecting sugar-planting. On the Burdekin delta (just 40 inches) irrigation is already being resorted to, and is found to be almost necessary.

Reasoning from the South Australian figures, I have called the limit of ten-inch winter rains in a great part of Australia the limit of agriculture. Let us test this by facts. Of course where the soil is very good, it will pay to farm with less rain; but as a fact, on the whole, there is very little permanent unirrigated culture beyond this limit. In New South Wales, where the lands on the dividing ridge and coast slopes are for the great part of very bad quality—and are also, especially on better soils, overgrown with bush and timber—persistent efforts have been made by Government ever since 1861 to settle agricultural colonists on the western plains. The attempt has utterly failed, and the above-quoted Report of Messrs. Ranken and Morris states the reasons of the failure of the previous land laws in this respect in very plain language. Speaking of the present Central Division and of the part of the Eastern outside the old settled districts, they say, "In 95 per cent. of this division an arable patch is worthless unless a certain amount of pasture is attached;" (the "patch" means the statutory square mile), and they then find upon the voluminous evidence before them, and in

¹ According to Mr. Bell's (Bell Farm, Manitoba) last estimate. The lowest figure on a small farm that could be quoted (some few years ago) by Messrs. Close and Benson, Iowa, on a 240-acre farm, farmed by similar methods, was nearly double.

² *Professional Papers of the Signal Service Department* (of the War Office) No. x. The areas arranged are, one would think, too wide and diverse. Small uniform areas carefully selected ought to give more instructive results.

accordance with "a general uniformity of opinion," that the least amount of pasture which will suffice to give a fair livelihood to a working family is 3 or 4 square miles, the latter being the figure more generally applicable. "It might have been recognised," say the reporters, when the old land law of 1861 was passed, "that settlement westward must in such a climate be based on a secured use of pasture."

As a matter of fact, there were in 1882 only 44,000 acres under cultivation in the (now) Central and Western Divisions, which is equivalent to a strip some 30 yards wide stretched across New South Wales from Victoria to Queensland. These two divisions cover two-thirds of New South Wales, and the east edge of the Central Division roughly corresponds to the 10-inch winter rainfall line.

In the Western Division, "the evidence showed" the Commissioners "that 9 square miles¹ is the least area that will form a homestead or allow of beneficial occupation." "These lands," they add, "were unlocked, or opened to settlement at the cost of £3,000,000, and only 300 householders, whether shanty-keepers, 'dummies,' or *bona-fide* selectors, have entered in, and it has cost the State therefore £10,000 a head to settle them *temporarily* on this land,—the rainfall being under 10 inches a year.

As regards lands in Victoria, not only outside but well inside the 10-inch winter rainfall limit, the Chief Secretary has just stated that "this further knowledge has been gained: that if agriculture is to be maintained at all in the northern areas of the colony, irrigation must be practised on a considerable scale. The experience, from 1875 to this day, of those who have attempted cultivation there, is one of painful failure, deprivation, and loss. If agriculture on the northern plains *has to be renounced*, it will mean the loss to us of a large number of the very best class of our population, . . . of men who, by their energy in other spheres of life, have contributed to make Victoria what she is. In fact, unless this area is irrigated, the population will be swept away, and the land must go back simply to sheep-farming."²

In South Australia, outside Goyder's line, the average rainfall at the nine oldest rain-gauge stations, which are mostly near the line, is 8 inches in the wettest (and coolest) seven months.³ Since 1880 the virgin soils here have been cultivated,—of course in picked spots, and wherever there was most rain. The extent under wheat, which is there the sole crop, was in 1880-82 over 500 square miles.⁴ The average yield therefrom in 1880-82 was just 3 bushels an acre,⁴ and in 1882, when the average rainfall of six counties, which comprise the bulk of the ploughed land outside the line, fell to 6·2 in the six months,³ the yield³

¹ This figure has also been adopted in the Land Act. But in May last no one had applied for any such block there, because of the difficulty as to water-supply.

² Page 25 of the reprint of the Hon. A. Deakin's speech.

³ Todd, *Report* for 1882, pp. 18 and 21.

⁴ "Statistical Map of Wheat Production" in the Royal Geographical Society's map-room. Catalogued as v. 8, 17 * * In deducing any formula from Mr. Todd's tables, this extension of wheat area beyond rain-gauges since 1880 must be taken into consideration.

in them was $1\frac{2}{3}$ bushels an acre. Since then it has been worse still. The farmers there have been generally throwing up the lands for which they had paid the deposit and part instalments of purchase-money, where the Government has not reduced the price. Thousands have been ruined.

AGRICULTURAL AREA OF AUSTRALIA.—The area of land in Australia outside the tropics, and within the 10-inch winter and 20-inch summer rainfall lines, as here traced (including West Australia), is less than 240,000 square miles—less, that is, than Austria-Hungary.

Unfortunately Nature, which has given Australia both rain and magnificent soils, has in large measure withheld the one gift where she bestows the other. The two gifts lose most of their value, because they do not coincide. If the heavy rains fell on the good soil Australia would be rich enough. The old settled districts of New South Wales, which form the central three-sevenths of the Eastern land division, cover some 40,000 square miles. They comprise "great stretches of waste, not only the most sterile in New South Wales, but about the poorest (as regards soil and capacity for production) in Australia." In one half of this land division (the Central and North-Central half), comprising, as it does, some of the best lands in the colony, settled for the last sixty years, and with easy access to the capital and to the sea-board, "more than half the area is too poor to be occupied with advantage under any tenancy." The same description applies to most of the coast slopes south of Sydney. "Limited spots of fertility" are there "interspersed among rugged and densely timbered ranges, while much of the country is so barren that its occupation is not likely to be hastened by any legislation;" and "as for the *unsold* land in the old settled districts generally, nine-tenths of them, according to a competent witness, would be dear at 5s. an acre," and in no part of the table-lands about the dividing ridge that he had seen would the land keep a sheep to the acre, "though by improvement it could be made to carry one and a half."¹ As a rule the soils overlying the extensive coal measures here and in Queensland are poor—for instance, those on the Upper Hunter.

In West Australia a large part of the rainy corner is sandy and very inferior.

The better soils on the coast slopes in Australia, where there is a rainfall of 30 to 38 inches and more, are generally heavily and thickly timbered, and the cost of clearing such land has been put by the Chief Secretary of Victoria as high as £10 an acre.

In the interior, on the other hand, where the streams issue out on the almost treeless plains of the Darling and Murray basin, there is generally rich soil, and a climate very like that of South California or the Cape,

¹ These quotations are from the Report of Messrs. Ranken and Morris, slightly condensed, but not altered in phraseology. The witness last cited had apparently spent half his life in the profession of prospecting for good spots under the free selection system. See further the details in the appendices to the Report.

excellent for viticulture. But the supply of water in these streams, like the rainfall on these plains, is very small.

This water-supply has been measured. The average discharge of the Murray at Albury, together with that of all the waters it receives from New South Wales below Albury (for a period of five years, 1879-84), was estimated to be equal to a mean continuous flow of 11,500 cubic feet a second. Nearly one-third of this was at Albury. A great proportion of the other two-thirds flows in summer floods, which it is not easy to utilise.

The other *available* waters of the Murray basin (*i.e.* its tributaries in Victoria) amount apparently to about 1000 cubic feet ¹ per second per annum; but here winter rains prevail, and the average flow in the winter half-year is 1300 cubic feet a second. The estimated amount of land which could be irrigated thereby, 10 inches deep in winter, is 560,000 acres, or 875 square miles, and 230,000 acres, or 359 miles, could be also irrigated in summer 15 inches deep.² The total average amount of water flowing into the Murray at or below Albury is hardly one-seventh of the average flow of the Rhone, or of the Po. The so-called rivers of these interior basins, so conspicuously marked on the map appended to this article, are mostly miserable things, flooded once or twice a year for a few days, and almost dry for the rest of the year. Arabs would call them "khors" or "wadys."

South Australia has no running waters at all worth mentioning, except the Murray, which Victoria and New South Wales hope to use up between them.

IRRIGATION.—The value of water artificially applied to land by irrigation can be proved more directly than the value of rain. There are data in several countries similar in climate to South Australia, Victoria, and the interior of New South Wales.

In the Punjab the excess of yield on irrigated lands over that on dry lands averages 10 bushels an acre: the amount of added water averaging 10 inches. The water is used wastefully and to excess—in fact, some lands have been super-saturated.

Wheat-growing, however, to quote the Chief Secretary of Victoria, the author of the new Irrigation Act there, is the "lowest and worse" use of irrigated land, though, for all that, it is widely practised at present in the Rocky Mountain States of America.

In South Australia it has been found that fruit-growers are perfectly able to pay ³ 2d. or 3d. per 1000 gallons (3s. 9d. to 5s. 7d. per inch upon an acre) to grow irrigated fruit, and export it to Europe at a profit.

¹ It is calculated that this amount can be put on the land: some would be lost by soakage, evaporation, etc., before it got there.

² Table appended to Hon. A. Deakin's speech on water-supply. Part of the Murray water at Albury belongs to Victoria. I cannot find the actual measurements of the streams.

³ Speech of the Honourable A. Deakin, Chief Secretary of Victoria, as reprinted, p. 60. (To be had at the Victoria Government Agency in London.)

In Spain the peasants of Murcia, who, according to M'Culloch, are "proverbial, even in Spain, for their indolence and apathy," buy their water every morning during the irrigating season at auctions. The average price at Lorca of the water so sold is 5s. 4d. per inch on an acre, which is equivalent to £2300 *per annum*¹ for a constant perennial flow of a cubic foot a second: and Mr. Higgin gives the Lorca price as a fair example.

In California it seems that in more than one place vine-growers have been paying 5d. per 1000 gallons (9s. 6d. per inch per acre) for water.

In the Cape first-class lands at Oudtshoorn, with water attached, have fetched prices running up to £250 an irrigated acre. Dry lands would be worth at the very outside £3. This price, however (and probably the flow of water also),² is small compared to the Spanish: for in the irrigable districts of Murcia and Valencia, where land and water are owned and sold together, irrigated lands, with the water that it is customary to use and enjoy therewith, fetch from £250 to £400 an acre, according to quality and situation: dry lands in the same, *i.e.* irrigable districts and neighbourhood, are worth from £7 to £20 an acre, the latter being quite an outside price.¹

Presuming the value of water in Murcia and Valencia generally to be the same as at Lorca, it follows that some 94 inches of water a year are usually therefore (and profitably) used up on the good lands irrigated, and this must be during a period of probably not over nine months, since the streams dry up in summer. As oranges are widely cultivated, and as rice used till recently to be the staple crop in Valencia, this is not strange.

The value of water in South California, the Cape, and also in Australia, is enhanced by the cultivation of the vine. Their climates are exceptionally favourable; for the vine, if it had sufficient moisture below, yields most and best in a very hot dry summer like theirs.

As stated above, every five inches of rainfall that can be collected off a given catchment area, and brought to market at Spanish prices, is worth as much as the same area of first-class irrigable, but unirrigated, land in Valencia itself. This is worth noticing, since the natural rainfall at Valencia is 17·7³ inches per annum, or 12 inches in the winter six months; yet this and the land together are only worth £20 an acre at the outside. If the rainfall upon one acre all fell in one corner and left the rest desert, the property would apparently be greatly improved as a whole.

As a further deficiency of rainfall would have to be made up by pur-

¹ *Commercial and Industrial Spain*, p. 93. In the notice of this book in the last May number of the *Scottish Geographical Magazine*, the "per annum" was omitted.

² For wheat fetches 5s. to 6s. 6d. a bushel at Capetown, this being the range of price in the last five years, and it does not appear to be grown much under irrigation. If water was worth less than it is at Lorca it would be irrigated.

³ This is for the years 1857-74 and 1876-80: at Murcia (for 16 years) 12·7, at Alicante (for 25), 13·6 inches.

chasing water at some 5s. per inch per annum on each acre, the very best land, if it had only 8 inches of rain in the winter, or 12 annually, would be worth next to nothing¹ even on the Mediterranean coast, and this, I believe, is the fact why these dry areas or *despoblados* are uninhabited and unused.

Irrigation manures as well as waters the land, but the value of the silt it deposits varies very much. The crops on the delta of the Kistna (Hindustan) are said to be 50 per cent. better than those on the adjoining delta of the Godaveri, on this account.² One must therefore reason with caution about water-values.

It should be mentioned that proper irrigation in any country is impossible as long as the English common law of riparian rights prevails. Victoria intends to abolish it root and branch, and to vest the ownership of all running waters in the State. In California a recent decision of the Appellate Courts of the State upholding it has brought all irrigation enterprises to a standstill, and it will oblige California to do the same, unless she prefers to see South California secede and become a separate State.

Our law says that water ought to flow as nature makes it flow. In a dry country this is to waste it entirely. It ought not to be allowed to flow thus an instant longer than can be helped. The law says that each riparian owner is entitled to the use of a reasonable amount. One might as well make a London street fountain run with good wine, and say that each man in London should drink from it reasonably, or send a cartload of sovereigns down Whitechapel, and say that every householder, especially the last one in the street, was entitled to help himself to a reasonable amount.

Has South Australia any right to have water flowing in the lower Murray? The question will soon require, I fancy, the decision of the Privy Council. New South Wales will soon follow the example of Victoria. South Australia is already securing a Californian firm of irrigation-work contractors to see how best to divert the Murray in South Australia. If any water is to flow there, a most inordinate amount will have to be let flow down from above, for three-quarters or more of a small flow will soak, evaporate, and waste away in the long and slow descent, all of which will soon be worth £2300 per annum for every cubic foot a second of annual average flow.

Investors and promoters of emigration would, I think, do well to consider and verify the considerations above stated with reference to the value of rain and irrigation water, and to the scarcity of both in Australia.

¹ One must reckon fee-simple value at about sixteen years' purchase (6 per cent.) in Spain, according to Higgin.

² See General Sir A. Cotton's letter to Mr. M'Coll, the persistent advocate of irrigation in Victoria. *Papers presented to the Legislative Assembly, Victoria*, 1883, vol. i., in a return on surface irrigation.