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For India as a whole, the crop occupies only 1·3% of the total cultivated area; in some parts the proportion is much greater while in others it is much less. It is only in the United Provinces that this proportion is as high as 5·04%; i.e. nearly 4 times the All-India ratio. In Bihar and Orissa and the Punjab, it is slightly greater than 1·3%, in Bengal and in the North West Frontier Province, it is slightly less than 1·3%. In the other sugar-growing tracts of India, the proportion is much less than this (Vide Appendix II.)

It is not merely the total area under a crop which determines the importance of that crop, but in any region the actual proportion of the area under a crop to the total cultivated area is a much better index of the relative importance of that crop. This is well brought out by the map showing the 'Distribution of Sugar Cane Area in India.' Thus Mysore has nearly 90% of the sugar cane acreage of Hyderabad, but in Mysore the crop occupies 0·75% of the total cultivated area while in Hyderabad it is as low as 0·18%; i.e. to Mysore the cane crop is nearly 4 times as important as it is to Hyderabad although the total area under the crop in Mysore is less than that in Hyderabad. Many other similar examples can be cited and column 7 of Appendix II, brings it out clearly.

Table I

India (excluding Burma)	1921-22	1925-26	1931-32	1934-35
Total cultivated area in acres	269,781,428	272,563,199	281,172,401	280,271,501
Total irrigated area in acres	54,760,870	54,299,873	56,986,382	59,183,304
Percentage of total irrigated area to total cultivated area	20·3	19·9	20·3	21·1
Total area under sugar	2,503,807	2,801,230	3,102,899	3,635,518
Percentage of total area under sugar to total cultivated area	0·9	1·0	1·1	1·3
Total irrigated area under sugar	1,711,807	1,824,373	2,122,638	2,174,635
Percentage of total irrigated area under sugar to total area under irrigation	3·1	3·4	3·7	3·7
Percentage of total irrigated area under sugar to total area under sugar	68·4	65·1	69·3	60·8

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Table II

Period	Increase in total cultivated area	Increase in total irrigated area	Increase in irrigated area under sugar cane	Increase in area under sugar cane	Ratio of 3 to 4 percentage	Ratio of 3 to 2 percentage
	1	2	3	4	5	6
1921-22 to 1925-26	2,781,771	—460,997	112,566	298,023	37·8	—
1921-22 to 1931-32	11,390,973	2,225,512	409,245	556,980	73·5	18·4
1921-22 to 1934-35	10,490,073	4,422,434	459,514	1,068,502	43·0	10·4

Note the reduction of percentage in columns 5 and 6 of Table II above since protection, 1932.

The above statistics in Table I prove the importance of irrigation to this crop. More than 60% of the total area under sugar is irrigated. It is noteworthy that there has been a diminution in the proportion of irrigated to total acreage. In 1921-22 it was as . as 68·4%, it came down to 65·1% in 1925-26 while in 1931-3 reached the peak position of 69·3%. Since 1932 the proportion l been diminishing steadily and in 1934-35 it was only 60·8%. T. percentage of total irrigated to total cultivated area in India has bee fairly constant about 20% for the whole period 1921-31. In 1934-35 it was nearly the same, 21·1%; even if it is construed as a variation it is only an improvement in the conditions of irrigation. For India as a whole therefore, the increase in sugar cane acreage has very little to do with the improved facilities for irrigation. This conclusion is more amply brought out by a study of Table II above. 1921-22 has been chosen as a base year for comparison and these ratios bring out clearly the role of irrigation in the increased cultivation of the crop for the whole of India. Based on these statistics, the following conclusions can be arrived at:—

1. The increase in irrigated area under sugar cane, when expressed as a percentage of the increase in area under sugar cane has been diminishing since 1931-32. (i.e. since protection was given to the industry).

2. Equally well, the ratio of the increase in irrigated area under sugar cane to total irrigated area has also diminished since 1932.

3. Increase in sugar cane acreage has very little to do with the increase in facilities for irrigation. The last column 6 of Table II shows that the increase in irrigated area has been at a faster rate than increase in irrigated sugar cane acreage, (nearly twice as much).

4. Column 5 of Table II shows the influence of irrigation on increase of acreage under sugar cane. The last two ratios show that during the period 1932-35, the proportion of the rate of increase of irrigated area under sugar cane to total increase in area under sugar cane was much less than during the period 1921-31.

It is therefore clear that for India as a whole, the increase of acreage under sugar cane has not been due to the better facilities for irrigation. Probably therefore it has increased since 1932 due to other economic factors. This however does not mean that there are no regions in India where increase in acreage is not due to the improved conditions in irrigation. There are large tracts like the Central India States, Hyderabad, Rajaputana states etc., where the increase in acreage under sugar cane can only be attributed to the improvements in irrigation.

It has already been shown that sugar cane occupies slightly more than 1% of the total cultivated area in India. It was 0·9% in 1921-22, 1·1% in 1931-32, and 1·3% in 1934-35. India is a country where irrigation plays an exceedingly important role in agriculture and it is found that the proportion of irrigated area under sugar cane to total irrigated area is nearly 3 times as great (3·7 : 1·3) as the proportion of total area under sugar to total cultivated area in India. It is the more important crop that is grown under irrigation and hence the importance of this crop becomes obvious.

Much of the increase in acreage under sugar cane has been since 1930. Appendix III shows the total and irrigated acreage ... cane since 1930 till 1935, the last year for which offi... ...ctor ...able. The heaviest increases are in Bihar ... Rajaputana states. The climatic require... period 1915 to ... appendix I) are such that irri... ...ease. No correct stat... ...cted in the percentage ... ...t of irri... ...japutana ...o be mis... ...se, both ...tically in both these regions the rainfall is inadequate and unless amply supplemented with irrigation the crop cannot be grown successfully. Hyderabad and the Rajaputana States are perhaps the best examples which show that with increased facilities for irrigation even previously unirrigated crop becomes an irrigated one; in other words, the crop is a serious competitor for irrigation water, the ryot using the irrigation water in increasing quantities for the cane crop. The increased acreage in both these areas is due to better facilities for irrigation. In Hyderabad it is mostly in the area irrigated by the Nizamsagar that the increase is seen.

Central Provinces and Berar are regions where the increase in total acreage is great—nearly 30 to 40%—but this increase is proportional to the increase in irrigated acreage. The rate of increase in C. P. & Berar has been very slow since 1923, indicating probably that maximum has nearly been reached.

United Provinces, Mysore and Bombay have all shown a steady growth, though a smaller one—about 20 to 25%—the average increase per year being fairly constant. Both in Mysore and in Bombay the increase in acreage is due to the better facilities for irrigation. In the United Provinces irrigation is necessary to supplement the rainfall, but the increase in acreage far exceeds the increase in irrigated acreage. It indicates that most of the area that could be irrigated has already been irrigated and the ryot has extended the area of cultivation without a proportionate increase in irrigation, thus gambling with the monsoons. In the Punjab also the needs for irrigation are similar, but the increase in total acreage is nearly double the increase in irrigated acreage. The Punjab ryot also gambles with the monsoon like his U. P. neighbour.[25]

It is however noteworthy that in Madras, in tropical India where irrigation is essential for the cultivation of the crop and where it is cultivated by a better class of agriculturists,[26] th... increase in irrigated acreage equals the increase in ... of the crop

Again, where due to climatic reasor... ics, the following sary as in Bengal, a diminution in ... seen. It is only in Assam th... ...ated area under sugar cane, when ex- ...tage of the increase in area under sugar cane has

25. As ng since 1931-32. (i.e. since protection was given to since then cessful gam the insect

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... cane 33-34	Area under improved cane 33-34	Total area under sugar cane 34-35	Area under improved cane 34-35	Increase in area in improved cane in 34-35 compared to 33-34	Percentage of improved crop to total crop in 34-35	Percentage of increase in improved crop to total area under improved crop in 33-34
...432	1,445,000	1,844,580	1,671,000	226,000	90·5	15
...650	187,300	520,339	200,600	13,300	38·5	7
34,554	42,095	138,568	57,943	15,848	41·9	38
76,832	5,528	83,473	11,070	5,542	13·3	100
256,600	113,304	276,200	170,762	57,458	61·8	51
49,391	201	42,844	45	156	—	—
418,000	297,351	444,700	358,363	61,012	80·6	20
28,806	?	28,890	?	—	—	—
35,485	10,027	35,934	7,836	—2,191	21·8	—
40,334	10,583	45,525	20,498	9,915	45·0	94
46,472	6,567	50,580	14,359	7,792	28·4	118
3,424,072	2,295,257	3,635,518	2,512,476	217,219	69·1	9·4

Note that the increase in acreage under improved cane is more than the increase in total acreage under cane.

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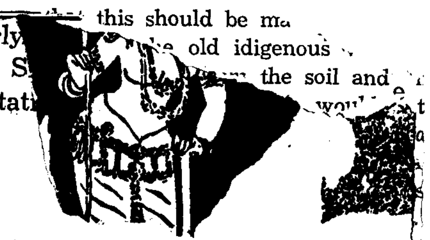

In the United Provinces, Bihar & Orissa, the indigenous canes are now almost extinct, occasional small patches being met with only in the interior. In Bengal and the Punjab the new and better varieties of the Coimbatore canes grow in popularity.

Acreage under Sugar Cane

Year		Total acreage	Acreage under improved varieties	Average Cane production in tons per acre
1931-32	..	3,102,899	1,170,478	14·1
1932-33	..	3,445,870	1,845,788	14·9
1933-34	..	3,424,072	2,295,257	15·3
1934-35	..	3,635,518	2,512,476	15·3
1935-36	.. (Estimate)	4,020,000	3,071,153	15·3
1936-37	.. (do.)	4,431,000	3,500,000	15·3

These statistics clearly show that in 1931-32 slightly more than 1/3 the total area under cane was under improved crops, but by 1934-35 the area under improved crops was more than 2/3 the total area under the cane showing thereby a phenomenal increase in the acreage of better varieties. If the increase goes on steadily, it is sure that in a few years, the cane cultivation of India will be of the superior quality of the canes. It is however surprising that in spite of this, the average cane production in tons per acre has not proportionately increased.

The yield per acre is highest in the tropical parts of the peninsula; in Madras it is 6,224 lbs while in Bombay it is 5,422 lbs. The Punjab has the lowest yield,—1764 lbs,—Delhi is slightly better (1,792 lbs). The yield in the United Provinces is poor (3,463 lbs) as is that of Bihar (3,287 lb) and Orissa (3,659 lb) or the Central Provinces (3,584 lb). The yield of Ben[illegible] ... [illegible]tter (4,127 lbs). In respect of the yi[illegible]
content or average pem th[illegible]ea under sugar cane, when ex-
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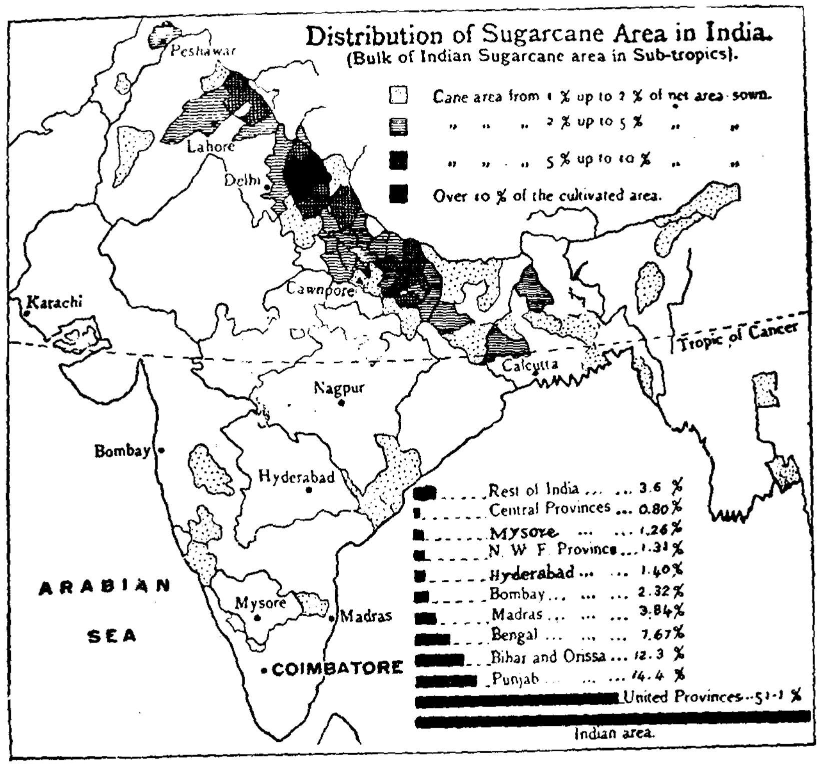
manures and fertilisers, (4) the lack of suitable seeds; (5) the lack of water; (6) the disease in the cane crop and (7) insect damage as in the Punjab and the United Provinces.

It is true that the acreage under improved varieties has increased phenomenally in the near past, but it is often forgotten that these



improved varieties often demand more manure. Unless artificial manuring is done, the soil will diminish in quality very rapidly.[27]

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the [illegible]od 1915 to 30. S[illegible] [illegible]andhi *Sugar*
inc[illegible]. No correct stat[illegible] [illegible] his annual
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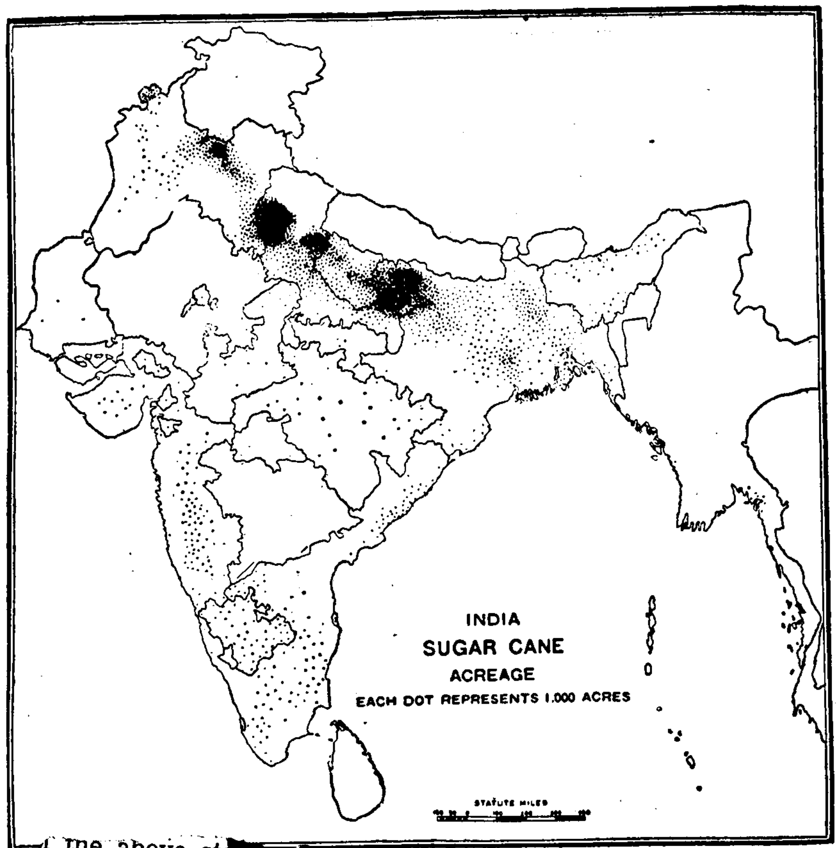
27. The Director of Agriculture, Bihar states that "the development and [illegible]re canes have conferred a substantial benefit on the [illegible] this should be maintained. The Coimba-[illegible]e old idigenous varieties, but they [illegible] the soil and [illegible]nless this is [illegible] wou[illegible]

The sugar factories in India do nothing to foster the cultivation of the cane although the cost of the cane is nearly 2/3 the cost of the final product. It is only in Bombay that the cane grower is the capitalist so that the holdings are large. In his annual report on the Department of Agriculture, Bombay for 1935-36, the Director says that the factories have their own cultivation for about 11,566 acres (more than 1/8 the total area under cultivation in the Presidency) and the yield in this tract is nearly 3½ tons of refined sugar per acre. (Total yield is about 39,115 tons). In the United Provinces which is the largest sugar-growing tract of India, the conditions are the exact counterpart of this. If the factories in the United Provinces foster the growth of the early and late ripening varieties, the yield would be much better and the factories would have a much longer working season. If the industrialist and the agriculturist were to work in co-operation, the yield can be increased so that the miller gets his crop at a reduced price without reducing the income of the cultivator. A part of the profits in the industry must be ear-marked for investments in the fields,—irrigation projects if necessary—and this should be considered as part of the capital expenditure.

In Mysore, in the Irwin Canal area the yield of the cane is about 40 tons of cane per acre; the average for the United Provinces and Bihar is only 15 tons per acre and even in the other parts of Mysore it is only 20 tons per acre. The Mysore Sugars Ltd. have instituted prizes for the best cane yields in one acre blocks and five acre blocks. The Mysore ryot co-operates with the plans and programmes adopted by the factory. The time of planting is adjusted to the requirements of the factory so as to obtain as long a crushing season as possible. The mills advance up to Rs. 500,000 for the cultivators and also employ a good trained staff to instruct them about pests, manuring, proper methods of cultivation etc. It is only in the Irwin Canal area that the factories work for 9 months and it is well worthy of emulation by the other sugar manufacturers.

The average cultivator of India is hardly aw... proved methods of farming or manurir ...es is poor (3,463 lbs) of varieties suitable to the soil ... issa (3,659lb) or the Central ...d of Ben... ...the vi... ...tter av... ...ssam the area under sugar cane, when ex... ...the increase in area under sugar cane has ...nce 1931-32. (i.e. since protection was given to

nal methods from year to year without effecting any improvements in the quality of the cane grown in his fields. Sugar cane crop is one of the most important cash crops of the country, the annual value of which is approximately Rs. 60 crores, (vide reply to the Council of State, February 1937) and the prosperity of the third largest industry in the country is closely linked with it. Demonstration farms and nurseries should be established to improve the conditions of the crop throughout the country.



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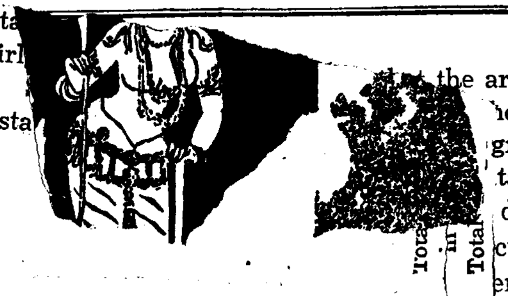

in further increasing the area under cane cultivation except in localities adjoining existing sugar factories. The sugar committee did not take any action in this matter as several relevant statistics (e.g. the consumption of sugar) were not available. In May 1937 the sugar committee expressed its opinion in favour of improving the quality of the cane crop by arranging zones, research etc. and against any further extension of the acreage. It is certainly true that the present area under cultivation meets the demands of the country and more attention should be devoted to improving the quality and lowering the cost of cultivation of the crop rather than increase the area. With the best qualities of cane being cultivated in increasing quantities, it is clear that within a few years, India without increasing the acreage under the crop, can, not merely be self sufficing as in the past as regards her needs of refined sugar, but could also hope to play a very important role in the world market in spite of the severe competition with Cuba, Java etc. Indian export of refined sugar has not met with considerable approval even from the Empire marketing board and perhaps that may to a certain extent—and only to a very limited extent account for the failure of the export trade in sugar. This however is not our main theme at present.

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Sugar Cane Cultivation in India

By

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(Continued from Vol. 15, No. 1, page 540).

The total area under sugar cane in India has been varying very considerably and the following tables (include Burma also) give the total acreage under sugar cane in millions of acres :—

1915-16	1916-17	1917-18	1918-19	1919-20	Average for the quin-quennium
2·669	2·730	3·153	3·179	3·008	2·948
1920-21	1921-22	1922-23	1923-24	1924-25	
2·887	2·699	3·044	3·232	2·837	2·940
1925-26	1926-27	1927-28	1928-29	1929-30	
2·993	3·245	3·227	2·836	2·751	3·010
1930-31	1931-32	1932-33	1933-34	1934 '35	
3·061	3·267	3·617	3·600	3·783	3·466

Average rate of increase per year for the period 1915 to 30=·14%
Average rate of increase per year for the period 1930 to 35=3·03%

From the above statistics, it is clear that the acreage un
sugar cane has been fairly constant—about 3 million acres
the period 1915 to 30. Since then there has been a re
increase. No correct statistics of cultivation are availa

1935 but it has been estimated by Mr. Gandhi in his *Sugar Annual* of 1937 that this increase has been continuing even since 1935 and his estimate of the area under cane sugar in 36-37 is 4·431 million acres. (Vide Appendix IV). The distribution of the crop in the various provinces of India are also shown in Appendix IV and it is obvious that by far the largest portion of the crop is grown in the United Provinces, the Punjab, Bihar & Orissa and Bengal. They have really been the most important regions for sugar cane from the earliest times of which we have definite statistics. The two maps of sugar cane cultivation appended herewith also bring out this fact very clearly.

It is found that the total cultivated area in India (excluding Burma) in 1934-35 was 277,270,610 acres of which sugar accounted for 3,635,518 acres forming nearly 1·3% of the total cultivated area. It might therefore appear to be an unimportant crop, but it should be remembered that the sugar industry is the third largest industry in India.[23] It has been estimated that there are nearly 20 million agriculturists who are sugar cane cultivators and their interests have to be zealously protected.[24]

23. Cotton comes first with 470 mills, a subscribed capital of 40 crores of rupees and about 400,000 workers. There are about 150 sugar mills working (178 registered) with a subscribed capital of about 7 crores of rupees and nearly 100,000 workers. In the Jute industry there are nearly 109 mills and a subscribed capital of nearly 20 Crores of rupees. Nevertheless, it should be borne in mind that neither the number of workers nor the amount of capital invested in any industry could be taken as absolute criteria regarding the importance of the industry. The shift system and the average output per employee have also got to be considered. Again, at best the sugar mills work only for about 150 days in the year. The number of agriculturists involved is perhaps a fairer factor to determine the relative importance of any industry.

24. The cane crop is the most important cash crop for the agriculturists of Bihar and the United Provinces and nothing has yet been devised to replace it. On the fortunes of this industry depend a very large number of ryots in both Bihar and the United Provinces. In a statement made by the Government of India (*vide* reply to a question in the Council of State dated 16th February 1937) it was stated that during 1935-36 the amount of 833 lacs of rupees was paid to cane agriculturists by the mill owners! From the available statistics of production, it is found that nearly 11,315,000 tons of cane were crushed and based on an average yield of 15 tons per acre, this shows that nearly 758,000 acres were under cultivation which supplied the factories. ...erage in the United Provinces and Bihar the two predominant cane ... acre represents the average holding for a family of five persons ...ue of almost every other part of India) and hence the factories alone ... nearly 3,800,000 agriculturists!

Province.	Average under Sugarcane in 1921-22	1925-26	1931-32	1934-35	Increase Percentage during 1921-35	Annual Percentage increase	Estimate cane acre in 1935-36	Estimate acreage 1936-37	Increase of Percentage for the period 1921-1937		Increase of percentage for the period 1931-37	
United Provinces (states included)	1,169,199	1,440,408	1,603,320	1,844,580	57·8	4·1	2,249,000	2,519,000	115·5	7·2	57·1	9·5
Punjab including the Punjab States and Agency States	414,625	392,027	532,442	520,339	25·5	1·8	474,000	551,000	32·9	2·1	3·2	0·5
Bihar & Orissa	305,900	290,200	302,846	444,700	45·4	3·2	478,000	490,000	60·2	3·8	74·0	12·3
Bengal	220,900	215,000	233,400	276,200	25·0	1·8	325,000	355,000	60·7	3·8	52·1	8·7
Madras (States included)	138,663	121,304	126,515	138,568	0·1	0·0	119,000	122,000	12·0	0·75	3·6	0·6
Bombay (States included)	58,703	69,790	72,044	83,473	42·2	3·0	122,000	126,000	114·7	7·2	75·5	12·6
North-West Frontier Province	34,439	48,124	44,268	42,844	24·4	1·7	59,000	72,000	109·1	6·8	62·6	10·4
Assam	40,972	40,636	31,332	35,934	12·3	0·9	37,000	38,000	7·2	0·5	21·3	3·6
Central Provinces (including Berar)	17,252	22,942	22,042	28,890	50·1	3·6	30,000	30,000	73·9	4·6	36·1	6·0
Hydrabad	31,623	54,624	35,393	50,580	60·0	4·3	59,000	58,000	83·4	5·2	63·9	10·7
Mysore	32,345	32,999	36,076	45,525	40·7	2·9	51,000	52,000	60·7	3·8	44·1	7·4
Central India States	6,634	6,344	10,779	22,411	237·8	17·0	?	?	?	?	?	?
Delhi	6,510	7,766	3,225	7,621	17·1	1·2	3,000	5,000	23·2	1·7	55·0	9·1
India—Total	2,503,807	2,801,830	3,102,899	3,635,518	42·7	3·1	4,020,000	4,431,000	77·0	4·8	44·8	7·5
Total cultivated area ~~in India~~	269,781,428	272,563,199	281,172,401	280,271,501								
Total irrigated area in India (excluding Burma)	54,760,870	54,299,873	56,986,382	59,183,304								
Total irrigated area under sugar in India (excluding Burma)	1,711,807	1,824,373	2,121,052	2,171,321								

The Geographical Aspects in Relation to the Physical, Chemical and Biological Conditions of the Red Hills Lake

BY

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(Continued from page 181 of Vol. XV, No. 2.)

C. DISCUSSION OF INTER-RELATIONSHIP

In the previous section a brief account of the seasonal changes in the physical, chemical and biological conditions of the lake water during the three years of 1933-35 has been given. It is now proposed to discuss the inter-relationship that exists between geographical factors on the one hand and some of the important physical, chemical and biological conditions on the other.

(i) RAINFALL, TEMPERATURE AND LAKE LEVEL.

The level of water in lakes depends upon climatic conditions, especially rainfall and temperature of the region in which they are located.

In the case of the lake under study, the maximum level is reached in December (north-east monsoon season) or in January (cold weather period) and the minimum in August or September (south-west monsoon season).

It is a shallow lake and is subjected to nearly uniformly high temperature for nearly nine months in the year. Besides the fall in level resulting from evaporation, water is daily drawn for the city's water supply throughout the year and for irrigation purposes periodically so that there is a gradual fall in level from January to September.

With the decrease in level, the shore all round is gradually increased and large tract of meadow land is seen towards the end of the south-west monsoon season. This land gets completely covered again with water during the next north-east monsoon season.

(ii) RAINFALL, WIND, AND COLOUR AND TRANSPARENCY

The lake water varies from yellowish green to whitish in colour. It is yellowish green from January to September and whitish during the remaining months. The yellowish tinge is most pro-

bably due to fine slime disturbed from the bottom and shore by wind action during the period referred to above. The greenish tinge is due to phyto-plankton, chiefly *oscillatoria limnetica* and *Aphanocapsa elachista var novo*, the two most dominant algae in the lake water. The whitish colour is due to clayey turbidity brought into the lake from its own catchment area, to water from Sholavaram lake, which gets it from the Kortalayar river during the north-east monsoon season.

(iii) TEMPERATURE OF AIR, BRIGHT SUNSHINE, WIND, SURFACE AREA, DEPTH AND TEMPERATURE OF WATER

The chief source of heat for lake waters is the sun. The surface layers are heated to a depth to which the sun's rays can penetrate and this depth is dependent upon their colour and transparency. The heat thus received in the surface layers is distributed to the deeper strata to a certain extent by wind among other causes. This temperature is also influenced to a certain extent by other causes such as rain and feeder streams or rivers, but these causes are only of minor importance. Lake waters lose their heat by radiation, by conduction to air and by evaporation.

A general account of stratification so far recorded in temperate and tropical lakes.

Thermal stratification in temperate lakes:

Studies of the seasonal changes in the thermal conditions of lake waters of the temperate region have shown that the entire depth of any deep lake is divided into three well defined strata in summer. First, there is a top layer of about 8-12 metres in thickness which is more or less of a uniform temperature. Its surface is the warmest part of the stratum and is subject to diurnal variation. This layer is known as "epilimnion." The thickness of the epilimnion in temperate regions varies according to the amount of solar heat available, but the maximum depth of this layer is about twelve to fifteen metres.

Immediately below this layer is the stratum of rapid cooling known [illegible] "thermocline", "sprungsicht," "metalimnion," "transition zone," "discontinuity [illegible] layer" etc. In this layer which may vary in thickness from one metre or [illegible] up to three metres, the fall of temperature per metre is greater than 1°C and [illegible] much as 9°C per metre. About 60 to 70 per cent of the [illegible] temperature is found in this stratum (Birge and Juda[illegible] The change in temperature from the epilimnion to the th[illegible] is fairly marked, whereas the [illegible]

Red Hills Lake

The lake investigated by the author is a tropical one and situated at nearly sea-level. It is very shallow, its maximum depth being about 25 ft. (7 m). A definite stratification is observed in the lake, but this stratification does not remain undisturbed for a long period like that of the lakes of the temperate region or like that of the Javanese etc. lakes investigated by Ruttner. In fact the stratification does not last continuously even for a single day. In the early morning there is no stratification, but as the day progresses, the surface layers get heated and a fairly well expressed stratification is formed in the hot part of the day, and it is destroyed in the night. So, this is a very peculiar type of stratification in that it is formed easily during the day time and destroyed every day, during the night so that in the mornings no stratification is seen. The term "Diurnal temporary stratification" may be used to distinguish this type of stratification from that found undisturbed over long periods, say, for a whole season as seen in temperate lakes and in the larger lakes of the tropics such as those of Java, Sumatra and Bali investigated by Ruttner. It also closely resembles what takes place in the surface layers of some temperate lakes (Birge and Juday 1912) on a bright, sunny, summer day and also to the phenomenon recorded by Jenkins (1929, 1932), Beadle (1932-34, p. 174) Worthington and Beadle (1932) and Worthington and Ricardo (1936 p. 58) in the surface layers of some East African lakes. They state with reference to one of the lakes "Both graphs indicate some mixing of the water near the surface down to a depth of about 5 metres during the night but there were no signs of a turnover." (Worthington and Ricardo l.c.). Worthington and Beadle (1932, p. 55) make a general statement from their observations of a number of East African lakes. "As a general rule, the water from the surface to a depth of two or three metres heats up several degrees during the day, and complete mixing takes place at night, so that from midnight onwards the temperature curve is vertical or even rev[illegible] in the upper fe[illegible] metres as illustrated in [illegible] Fig. I for lake Naivasha." Jenkins (1932 p. 550) has st[illegible] temperature [illegible]ed as follows: "Even at mid-day only slight temperature gradients were developed, and there is evidence that, after the night cooling, the top few metres of water may be distinctly cooler than those below (Jenkins 1929, p. 574). This in itself leads to [illegible] mixing of the layers affected, and may even extend to the bottom of the shallower lakes; in any case during these daily inversions of temperature there will be isothermal stages when the water, being of the same density throughout, will be readily mixed by the wind. This mixing, for which there is considerable evidence

is aided in the alkaline lakes by their extreme shallowness and by the regularity of the wind." What takes place daily in the surface layers of deep lakes like Naivasha, takes place in the entire body of the water in the Red Hills lake daily, since the maximum depth of the lake is only 5-6 metres. In fact the stratification of the Red Hills lake would be considered by Worthington and Beadle as merely a case of daily heating and cooling of the whole body of the water, since the lake is shallow; and that is really taking place in the Red Hills lake.

The temporary stratification formed in the Red Hills lake is shown in Tables IX (Ganapati 1934, 1935) and graph I (Ganapati 1934).

It is interesting to note that within this stratification, there is a region of nearly uniform high temperature near the surface and a region of greatest fall immediately below it and finally a region of more or less uniform temperature which however may gradually decrease towards the bottom. These three regions may be compared to the epilimnion, thermocline and hypolimnion of the temperate lakes during summer and to the larger lakes of the East Indies investigated by Ruttner. It is again interesting to note that the amount of the greatest fall is seen generally in March and April. It is just possible therefore to differenciate a temporary epilimnion, a temporary thermocline and a temporary hypolimnion within this temporary stratification, during the short period of its occurrence daily. The author believes that a similar temporary stratification with the three thermal strata would be found in the surface layers of the East African lakes, which get heated up during day time.

Detailed observations on shallow lakes of the type of the Red Hills lake over a long period have not been made so far in the tropics. The interesting point about such lakes is that a temporary stratification is fairly well developed by the middle of the day, and is destroyed at night. But in the case of a small pond in Calcutta Museum, Hem Sing Pruthi (1933) found the least difference (0·5°-[illegible]·0°C) between the surface and bottom in December and January and greatest ([illegible]·3°C) in summer (April to June); that there was complete stratification during the latter period; that in November and December there was a decrease in temperature difference so that the stratification of the water was disturbed; and that finally in January when the difference was least, a complete mixing of the waters took place. That our experience with the Red Hills Lake is extremely different has been sufficiently explained above.

Classification of the Red Hills Lake based upon its thermal conditions.

Forell (1895, cited by Whipple, 1927) was the first person to study the thermal relations in the various strata of lake waters. He classified the lakes of the temperate region into three types from their thermal conditions—polar, tropical and temperate. " Polar " lakes are those in which the entire mass of the water has always a temperature lower than 4°C. The surface layers are colder than the bottom layers exhibiting what is known as an " inverse " stratification. In " tropical " lakes, on the other hand, the temperature always remains above 4°C in all the layers. The stratification that is seen here is " direct " stratification. Their waters show highest temperature near the surface in summer and the temperatures decrease with the depth. " Temperate " lakes show the conditions of " polar " lakes during winter and of " tropical " lakes in summer. The temperature of the surface water in winter is lower than 4°C but during the rest of the year is always higher than 4°C.

Whipple's (1927) modification of Forel's classification is as follows: He classifies each of the above three types into three sub-groups: (i) lakes whose bottom temperature is near 4°C throughout the year and having only one circulation period possibly in winter; (ii) lakes whose bottom temperature varies but not far from 4°C and having one circulation period in winter and (iii) lakes whose bottom temperature is very similar to that of the surface and having practically a continuous circulation throughout the year.

None of the truly tropical lakes so far e.g. the lakes of Java, etc., investigated by Worthington etc., and the South Indian lakes investigated by the author, can come under the first two groups of tropical lakes according to Whipple's classification, since the bottom temperatures of these lakes are far above 4°C and often come very close to that of the surface (within about 5°C). The lakes that can come under these two groups of Whipple are those of Italy, which in a way belong to the warmer parts of the temperate region and can be considered tropical only from a North European or North American point of view, who will consider the climate of Italy as really tropical. Thienemann (1931, p. 213) for instance calls them " Warm " lakes.

The tropical lakes of Java, Sumatra and Bali, East Africa and South India referred to above may come under Whipple's third group of tropical lakes, since as already pointed out, the bottom temperature differs from the top only by a few degrees.

In this third group, according to Whipple's definition circulation of water takes place continuously throughout the year from top to bottom. Worthington and Riccardo (1936, p. 64) mention that in the East African lakes complete mixing takes place during windy months. They state " the mixing of the water is probably helped by strong winds which are prevalent at certain seasons on most of the lakes." The depth to which wind could be effective in mixing up the waters depends, according to Ruttner (1931, p. 407) on the surface area of the lake. Since the East African lakes have a large surface area (more than 10 sq. Km.) and are comparatively shallow, the waters of these lakes can be completely mixed up when a strong wind prevails. Worthington and Beadle (1932, p. 55) state in another place "These results confirm Ruttner's conclusion with regard to area and wind mixing, since all of those lakes mentioned are of the larger type, with areas more than 10 sq. Km. and range up to the enormous area of Lake Victoria; but the wind effect, if responsible, produces even greater mixing in that no thermoclines were detected at any depth." From this statement it is clear that mixing is possible only during periods of strong wind and cannot be continuous and as such cannot conform completely to Whipple's definition, where he states that mixing is continuous throughout the year. Though this complete mixing is seasonal and not continuous, a partial mixing confined to the surface layers up to a depth of about 5 metres is seen continuously throughout the year. This mixing of the surface layers goes on daily. Worthington and Beadle (1932, p. 55) state " As a general rule, the water from the surface to a depth of two or three metres heats up several degrees during the day and complete mixing takes place at night, so that from midnight onwards the temperature curve is vertical or even reversed in the upper few metres as illustrated in Fig. I for Lake Naivasha." In another place, Worthington and Riccardo (1936, p. 58) state with regard to Lake Bunyoni "Both graphs indicate some mixing of the water near the surface down to a depth of about 5 metres during the night, but there were no signs of turnover." So, these East African lakes fulfil the definition of Whipple only partially as regards the question of continuous mixing throughout the year. Continuous mixing throughout the year is seen but is confined only to the upper layers. And complete mixing occurs when the wind is strong but is not present throughout the year.

Regarding the South Indian lake, it conforms completely to Whipple's definition. The bottom temperature is very similar to that of the surface and there is continuous mixing throughout the year. Since the lake is very shallow (about 25 feet) the entire body of the water gets heated up during the day and cooled during the night and behaves like the surface portion (upto 5 m.) of the East African lakes referred to above. The mixing is diurnal and continuous throughout the year. Owing to its wide area and shallow depth, a thorough mixing can also take place whenever the wind is very strong.

Coming to the lakes of the East Indies investigated by Ruttner, the bottom temperature recorded is very much above 4°C., the lowest bottom temperature recorded being 20·1°C (Ruttner 1931, p. 403). The bottom temperature is very near the surface temperatures, the difference being only 0·25°C to 5·5°C (Ruttner l.c.). So from the standpoint of temperature, these lakes can come under Whipple's third group. But as regards the question of circulation, complete mixing takes place owing to wind and cooling in the case of certain lakes like D. Bratan (Ruttner l.c. p. 392) and partial circulation only in others like D. Batur (Ruttner l.c. p. 397). But in lakes with less than 2 sq. Km. of surface area the wind cannot bring about the complete mixing of the waters below a certain depth from the surface. The mixing would be confined only to the upper portion of the lake. The diurnal heating and cooling also, as in the case of the East African lakes brings about a mixing of the surface layers upto a depth of few metres (about 5 metres) (Ruttner 1931, p. 221 and Table I). But a complete mixing from top to bottom will not be possible in a lake of this type at any time during the year. In these lakes a complete turn over is possible only if there is a possibility of the surface waters becoming cooler than the bottom layers at some time during the year. From the data given by Ruttner for his several lakes, it looks as though such an occasion never arises at any time during the year. If such should prove to be the case, a complete turn-over can never take place at any time in these deep lakes. Ruttner (p. 446) states "Es ist leicht moglich, daβ sehr tiefe Seen nur selten bis zum Grunde durchmischt werden." This point has to be verified by further work viz. whether the surface layers in these East Indian lakes at any time during the year become cooled down to a temperature lower than that of the bottom.

So we can provisionally subdivide the third group of tropical lakes of Whipple as follows, basing, our classification upon the nature of their mixing:

(i) Lakes in which complete mixing takes place throughout the year. This is brought about by the daily heating and night

cooling and may also be brought about by strong winds occasionally e.g., South Indian lakes.

(ii) Lakes in which complete mixing is seen only periodically i.e. during very windy seasons. In addition to this a partial mixing confined to the upper layers upto 5-7 m. brought about by the sun's heat during the day and cooling at night may be seen continously throughout the year, e.g. East African lakes and some lakes of Java (less than 5 sq. Km. in area) and D. Braten.

(iii) Lakes in which complete mixing never takes place at any time during the year. Mixing in these lakes is only possible and confined to the upper region and brought about (a) periodically by wind whenever it is strong and (b) continuously by the sun's heat and night cooling and confined to the surface layers upto about five metres depth as in (ii).

(iv) Temperature of Air, Bright Sunshine, Wind, Surface Area, Depth and Dissolved Oxygen.

Lakes receive their supplies of oxygen from (i) the atmosphere (ii) from the photosynthetic activities of chlorophyll bearing plants in the water; and (iii) from bacteriological denitrification. From the atmosphere the surface layers of water get oxygen by mechanical admixture of air through the action of waves, so that when the lake water is in complete circulation, the entire lake is saturated with oxygen in the above manner. During the process of photosynthesis, the chlorophyll-bearing organisms "diminish or deplete the supply of CO_2 and increase the oxygen content beyond saturation." A very small amount of oxygen which is practically negligible is added through bacterial denitrification.

The quantity of oxygen present at any time in the day is the resultant of several factors such as diffusion, photosynthesis, respiration, the chemical processes of decay and of reducing substances. ... if the consumption of oxygen by vari-
(Carter 1936, p. 177). Now ... by decomposition of organic
ous organisms present in water and ... derived from the photo-
matter exceeds the supply of oxygen ... isms, then the amount
synthetic activity of chlorophyll bearing orga... process exceeds
is below the saturation point. But if the latt... supersaturate
that of the former than the water is saturated or ... ies,
(Brige and Juday 1912). ... in the

A general account of Oxygen distribution so far rec... in temperate and tropical lakes. ... effect a

(a) *Distribution in temperate lakes.*—A brief revi... earance
important literature on O_2 distribution of temperate lake

below: Birge and Juday (1912), Juday and Birge (1932) found definite O_2 stratification in the summer months in the lakes of Wisconsin and New York. They found that the oxygen distribution at different layers i.e. (1) above the thermocline, (2) in the thermocline and (3) below the thermocline differed considerably. Above the thermocline i.e. in the epilimnion, the O_2 content was near the saturation point or sometime even super saturated; in the thermocline, there was a rapid decrease of O_2 or sometimes was higher than that found in the epilimnion; and below the thermocline i.e. in the hypolimnion, it was practically absent, or present in very small amount or fairly high but less than that found in the epilimnion. Bronstead and Wesenburg-Lund (1912, cited by Minder 1924) concluded from their study of Furesee that (i) the oxygen distribution was homogeneous at the time of complete circulation, and this condition was attributed to convection currents bringing about a mixture of all the different layers; (ii) that during stagnation in summer months, the O_2 content decreased towards the depth; and (iii) that the most important source of O_2 for a lake was what it got from the surface layers.

Thienemann (1918) found from his investigations of the O_2 conditions of the different north-German lakes in summer that a definite relation existed between the bottom fauna and the O_2 content of the bottom layer. He also found that in lakes with a bottom fauna containing predominantly chironomid Tanytarsus, a relatively greater amount of oxygen down to the bottom; and in the lakes with a bottom fauna consisting chiefly of chironomus larvae, the bottom layers were very poor in oxygen.

Thienemann (1914) has considered the relation of the total quantity of O_2 found in a lake to the amount required to saturate the water at all depths, and the difference between the two amounts is a measure of the deficiency or excess of O_2 in the diff... of a lake. The vertical distribution ...) states "Es ist ...erent strata excesses at the various depth... selten ... oxygen and the deficits and It will be seen therefrom ... the different depths i... nas ... are given by him. (l.c. Table III). ...oint of saturation ... layer that the quantity of O_2 actually found at du... process ...ar becor... n the various series was below the theoritical that ... bottom ... except in a few cases where the O_2 liberated in

So we ca... photosynthesis in the region of the thermocline lakes of ...p the amount to the saturation point or higher. The nature of in the several layers was due to the demand for O_2 in the

(i) ... processes of aquatic organisms and in the decomposi- the year. ...anic matter.

(*b*) *Tropical lakes* have been studied by a few investigators—Fritsch (1907), Downes (1911, cited by Whipple et al, 1927), Ruttner (1931), Jenkins (1932), Worthington (1903), Hem Singh Pruthi (1933), Beadle (1932-34), Worthington and Ricardo (1936). Fritsch (l.c.) stated that the O_2 content of tropical lakes would be low considering their high temperature. Downes (l.c.) examined three reservoirs—Cocoli (9 ft.), Carabali (12 ft.), and Comache (26 ft.)—in the Panama canal region. He found 8.66 cc/l in the surface, 6·2 cc/l at 5 feet below, 0·8 cc/l at 7 feet below, and nil at 9 feet below the surface in Cocoli reservoir; in Carabali reservoir, O_2 was absent at a depth of 8 feet; and in Comache reservoir, it was absent at a depth of 14 feet.

Thienemann (1930) has stated that the deep tropical lakes are devoid of O_2 in their hypolimnion. Ruttner (1931) who actually investigated the lakes of East Indies has made a very valuable contribution to this important problem of tropical limnology. His important conclusions are detailed below.

(i) The oxygen curves of most of these tropical lakes resembled those of the eutrophic type of temperate lakes. Ruttner has given the following reasons for the presence of the eutrophic type and for the absence of the oligotrophic type of O_2 curves in them.

(*a*) Oxidation of organic and inorganic matter, respiration of animals—these processes by which O_2 was consumed took place in the entire depth of the water while the process of photosynthesis by which oxygen is supplied was confined only to the upper illuminated water mass.

(*b*) The vertical distribution of oxygen will therefore be dependent upon the quantity of oxidisable substances present in the lake water and on the rapidity of the oxidation process. The latter in turn was dependent upon temperature, and according to Vant Hoff's R.G.T. Rule the quickness of a reaction will be doubled or trebled with a temperature increase of 10°C. The bottom temperatures of tropical lakes is about 20°C higher than those of temperate lakes. This means therefore, that at the bottom of tropical lakes, oxidation process will be hastened at least four to nine times. If the oxidation process is hastened, then the concomitant oxygen consumption must be very great and result is the eutrophic type of O_2 curve. The O_2 stratification in the lakes of East Indies, therefore, is due to the great difference in the temperature in the tropholytic zone.

(ii) Ruttner found that a few days were sufficient to effect a sharply expressed O_2 stratification with the complete disappearance of oxygen at the bottom.

(iii) The lowest value observed by him was 61% saturation in the surface water of Ngebel-see. This figure did not represent the minimum occasionally reached in these tropical lakes, since he thinks that in some lakes much lower figures may be expected.

(iv) Supersaturation was generally very high and usually reached in the afternoons an extremely high figure. In one single instance, the value came up to the extremely high figure as 347%.

(v) During night time, a large portion of the O_2 was consumed by the respiratory process and very little was lost to the air.

(vi) Maximum amount of oxygen was not found at the surface but was a little below the surface as in lakes of the temperate region.

Jenkins (l.c.) found the surface water of lake Nakuru saturated to the extent of 113%, and the water at a depth of 1·75 m, only 18·2%. In the lake Elmenteita the percentage of saturation varied from 44·4% to 104·8%; and in Naivasha, from 40·7% to 86·9%. She concluded that "the comparative abundance of oxygen (see Table III) at all depths in these lakes may well be contrasted with the conditions in tropical swamps, since it cannot here, as there, be one of the limiting factors in distribution (Carter and Beadle, 1930, p. 249)".

Beadle (l.c.) obtained at station 30 in the Lake Naivasha at midday on 23-11-30, 5·46 cc/l; and at 18 m. depth, 3·54 cc/l; and on 26-2-31, 5·50 cc/l and 3·70 cc/l for the above. He has also remarked that the oxygen content from the surface to bottom was uniform at dawn and that at midday there was a considerable rise in that of the surface water to a depth of (probably) about 5 metres and that the surface water at midday was saturated to 94%.

The nature of the Oxygen distribution in the Red Hills Lake

From a study of the dissolved oxygen content in the several layers of the Red Hills Lake the following facts are noticed. In the early morning the entire vertical layer is homogeneous i.e. contains nearly the same amount of dissolved oxygen from the surface to the bottom; but as the day advances the surface layers contain slightly though definitely more oxygen than the bottom layers. This is illustrated by the data for January, February, March, April, July and August for 1934; and for January, February, April, June, the August and October for 1935 (Table No. X Ganapati 1934, 1935), ting the formation of a weak stratification. This is not

permanent but is destroyed at night so that in the morning the values are the same from the surface to the bottom.

In the afternoons when a weakly expressed O_2 stratification is formed, the differences between the surface and bottom layers do not exceed 1 cc/l (vide Table No. X l.c.). These small differences may be due to two causes: (i) photosynthetic processes of the chlorophyll-bearing organisms resulting in increased oxygen content in the upper layers, and (ii) mixing taking place daily in the night effecting a uniform distribution of O_2 from the surface to the bottom. If daily mixing did not take place, and a stratification of long duration resulted in the Red Hills lake, one should expect a considerably greater depletion of O_2 in the bottom layers, so that the differences also will be considerably greater. Thus, the small differences between the surface and bottom layers in the Red Hills Lake and the relatively high O_2 content of the bottom layers are indirect proofs of the diurnal mixing which takes place at night (Beadle 1932-34), Worthington (1930), Worthington and Ricardo (1936) and Jenkins (1934).

Diurnal variations.—The maximum amount of oxygen in the surface layers is shown between 4 and 5 p.m., and the minimum at about 7 a.m., as will be evident from the data for diurnal variations on 31-3-34 and 2-4-34 (vide Table X l.c.) Similar results have been obtained by Hem Singh Pruthi (1933), and by M. O. T. Iyengar (1926 p. 1180). The former found the Calcutta Museum pond water to be below saturation in the morning, almost saturated at 10 a.m., and supersaturated at 12 noon and 4-30 p.m. and decreasing after 5 p.m. and reaching the minimum at 10 p.m. M. O. T. Iyengar found the O_2 content was lowest at 6 a.m., and that it reached its highest level between 3 and 4 p.m., in the afternoon and thereafter declined gradually till the lowest level was reached at 6 a.m., on the following day. So, the fact that maximum content of oxygen is being reached at about 4 p.m., in the afternoon and the lowest value being recorded at 6 a.m., are also shown by the Red Hills Lake.

The amplitude of diurnal variations in the O_2 content of the Red Hills Lake was small, i.e., 0·61 cc/l on 31-3-34. M. O. T. Iyengar, also found similar small ranges (1·65—1·78 mg/l). It must however be pointed out that Pruthi found in the case of the Calcutta Museum pond water a greater difference between the minimum and the maximum amount of O_2 produced in the course of a day.

These diurnal fluctuations are due to a large extent to the photosynthetic action of the algal flora present in a piece of water. The greater the algal content, the greater the diurnal fluctuations, Butcher et al (1930). So, in the case of the Red Hills Lake, the small difference in the diurnal fluctuation only shows that the plankton algal population is comparatively very small.

Supersaturation in the lake water.

The quantity of oxygen found at different depths in the Red Hills Lake was also below the theoritical point of saturation except in a few cases where the O_2 liberated in the process of photosynthesis brought up the amount to the saturation point or slightly higher as in the case of the temperate lakes. A small or only slight supersaturation (109%) was noticed in January, February, and October 1935. This slight supersaturation indicates again that the lake does not support a vast growth of algae. The quantity of oxygen in the several layers on other occasions was less than the theoritical point of saturation; and this deficiency is to be ascribed to "the demand for O_2 in the respiratory process of aquatic organism and in the decomposition of organic matter" (Juday and Birge 1932).

Another interesting feature noticed in the Red Hills Lake is that the O_2 content was always lowest in the second half of the south-west monsoon season i.e. in August or September. At this part of the year the velocity of wind was low and the organic content of the lake water has been found to be at its maximum and the duration of bright sunshine was less. This is most probably due to the using up of the oxygen by the fairly large quantity of organic matter present in the water at this part of the year for oxidation purposes (Pearsall, 1923, p. 53 Juday and Birge l.c.). The oxygen content was highest in May, when the duration of bright sunshine was longer, velocity of wind higher and temperature also higher. It was also high during the last quarter of each of the 3 years. This was due to fall in temperature of air and water which increases the solubility of oxygen, brought in from the atmosphere.

Relation between the vertical distribution of oxygen and the vertical changes in temperature of the Red Hills Lake.

A definite relationship has been established between the vertical distribution of O_2 and the vertical changes in temperate lakes during summer months. Thermal stratification was almost always accompanied by oxygen stratification (Thienemann 1925). Ruttner (1931) has also made a similar statement in the case of the tropical East Indian lakes. In the case of the Red Hills Lake also we find a definite relationship between the two. A temporary thermal stratification is noticed by the afternoon and this is accompanied by a temporary stratification of O_2 also, as in the case of the East African lakes (Beadle l.c.)

Classification of the Red Hills Lake based upon its oxygen Conditions.

Thienemann (1914) classified the lakes of the Eifel district, Germany, on the basis of their thermal and oxygen relations in summer. He differentiated the following three groups. In the first group of lakes the three strata of varying temperatures e.g. the epilimnion, thermocline and the hypolimnion are present but the oxygen curve does not correspond with that of the temperature. In the second group, the three thermal strata are present but here the oxygen curve follows generally that of the temperature.

In the third group, no definite stratification is seen, the temperature being more or less uniform throughout. In these lakes the O_2 content also is uniform and shows no stratification.

Thienemann later on in 1920 rejected the third group and retained the first two groups. In 1928, he explained the scope of the two groups of lakes in still greater detail and while doing so, pointed out that all oligotrophic lakes would come under the first group and all eutrophic ones under the second.

Ruttner (1931) classified the lakes of Java, Sumatra and Bali into three groups on the basis of their oxygen conditions. The O_2 curves in these lakes generally followed that of the temperature in the three groups.

The first group consisted of all small lakes below two sq. Km. In this group there was a pronounced thermal stratification with a sudden fall in the thermocline region. Here the O_2 curves were nearly similar to the thermal curves. The surface layer was nearly saturated with oxygen, but lower down there was a gradual decrease and in the thermocline region there was a sudden fall. It was very poor in the hypolimnion being present only in traces or even entirely absent.

The second group consisted of the great lakes of the middle and south Sumatra of about 100 sq. Km. (excepting Tobasee). The epilimnion of these lakes extending upto a depth of 10 m. contained high values for O_2. In their thermocline, the fall of oxygen was more gradual and less steep than in the case of the first group and continued into the hypolimnion where it disappeared at a depth of 100 m, so that there is a general similarity between the oxygen and temperature curves. But the fall in O_2 is not so deep as in the first group owing to the greater surface area of these lakes and the consequent exposure of water to the mixing effect of wind.

The third group of lakes of more than 1000 sq. Km. area is represented by the two great Toba-basins of North Sumatra where the epilimnion extended down to a depth of about 30 metres and the thermocline was less marked and its lower limit could not be sharply differentiated from the deep hypolimnion. The oxygen conditions were also similar. The thick epilimnion extending to a depth of 30m. was saturated with oxygen. In the thermocline below the 30 m. layer the fall of oxygen was very gradual and merged into the hypolimnion where even at a depth of 425 metres zero value for dissolved oxygen was not reached.

As regards the Red Hills lake, it does not come under any of the above classifications. The thermal and oxygen conditions though similar are rather peculiar. A definite thermal stratification is observed in the lake but it does not remain undisturbed for a long time like those of the temperate region or of those of the East Indies. It does not, in fact, last continuously even for a single day. In the early morning there is no stratification, but as the day progresses, *a fairly* well expressed stratification is formed in the hot part of the day and is destroyed in the night. In the same way, there is a temporary oxygen stratification formed in the Red Hills Lake, which is daily formed in the afternoon and destroyed in the night. In the early morning the O_2 content of the several layers is the same, and as the surface layers get heated, the O_2 content also increases resulting in a fairly well expressed O_2 stratification, so that the temperature and oxygen curves resemble one another.

In Griffith's (1936) pool also which shows similar temperature conditions as those of the Red Hills Lake, the O_2 conditions are also similar.

(v) Temperature, Bright Sun-shine, Wind, Surface Area, Depth and Carbonic Acid.

Carbonic acid occurs in natural waters as free CO_2, or chemically combined with alkaline earth and alkaline metals. The latter is found in two different conditions: as "bound" CO_2 (mono carbonates) and "half bound" CO_2 or bicarbonates. All the three forms are of great significance in the biological economy of lake waters. The free CO_2 is used by plants in water during photosynthesis. When all the available "free" CO_2 is used up, the "half-bound" CO_2 (from 4/5 to 5/8) is then attacked and utilised (Brige and Juday 1912). When the first two sources are exhausted, the fully "bound"

CO_2 (or monocarbonates) may be utilized (Schutow 1926, Maucha 1929, Neresheimer and Ruttner 1929—cited by Juday et al 1935).

(*a*) Free CO_2 was not found at any time and in any of the samples collected from different depths during 1934 and 1935. It was, however, observed once on 23-12-33.

The absence of "free CO_2" may be due to (a) photosynthesis (b) marl-forming organisms (c) agitation of water and (d) evaporation of water taking place in the Red Hills Lake (Welch 1935). During photosynthesis which takes place almost throughout the year by chlorophyll-bearing plants, consumption of free CO_2 takes place (Juday et al 1935, p. 6, and Ruttner 1931). Hence free CO_2 is absent. Its absence may also be due to the activity of marl-forming organisms, which are also present in the Red Hills Lake. The several groups of organisms concerned in marl-formation are bacteria, algae, mussels, chara, higher plants and plankton organisms (Welch 1935, pp. 176-182). The sandy, wind-swept beaches of the Red Hills Lake contain marl; the incrustations on the wave beating region of the laterite bund, and on pebbles in the sandy beaches of the lake contain fine calcium carbonate incrustations. Also, chara and higher plants like Najas, Potomogeton etc., are covered with marl incrustations. This is inferred by the evolution of CO_2 when hydrochloric acid is added to these incrustations.

The third factor which is responsible for its absence is the agitation of water, caused by wind action which is very effective in getting rid of "free CO_2 and finally, on account of evaporation, there is probably also loss of half-bound CO_2 resulting in precipitation of monocarbonate. "This form is greatest in shallow lakes of large area where evaporation is most effective" like the Red Hills lake. Welch (1935).

(*b*) *Distribution of carbondioxide, bicarbonates and carbonates in temperate lakes*

A brief review of the distribution of the three forms of carbon dioxide in temperate lakes especially at the time of their thermal stratification during summer is given below. Birge and Juday (1912) found definite stratification of free CO_2 in the Finger lakes of New York during periods showing thermal and oxygen stratification. They found that (i) the free CO_2 was absent in the epilimnion; was present in fairly large amounts in the thermocline and in abundance in the hypolimnion; (ii) a very small quantity of the bicarbonates was present in the epilimnion, a fairly large amount in the thermocline and a still greater amount in the hypolimnion;

(iii) the carbonates were present in the epilimnion but were absent in the thermocline and hypolimnion.

As regards the general alkalinity of the water, they found that this was not uniform throughout but was greatest near the surface and gradually decreased downwards. They attributed the high degree of alkalinity of water in the epilimnion to several factors such as the free exposure to the atmosphere, the absence of much decomposition, the photosynthetic activity of the plankton algae present and the amount of sunshine available. The low degree of alkalinity in the hypolimnion was attributed by them to the presence of the large quantity of the precipitated, dead planktonic forms and the consequent increased decomposition of organic matter. The thermocline shows conditions approximately intermediate between those of the epilimnion and hypolimnion.

In the lake waters of north-eastern Wisconsin, Juday et al (1935, pp. 15-27) found that the vertical distribution of free CO_2 and the carbonates was as follows: The free CO_2 was almost uniformly distributed from the surface to the bottom in the shallow lakes of 6-13m depth, the uniformity being due to these lakes being subjected to considerable wind action. (ii) " A rather large variation in the free carbon dioxide content of the lower water was found in lakes ranging from 15 to 20 m in depth." (iii) A more marked increase in the quantity of free CO_2 in the hypolimnion than in the epilimnion was found in lakes of more than 20m. depth and (iv) in a few lakes there was a smaller amount in the thermocline than either above or below this stratum.

As regards the carbonates, some lakes showed uniformity of distribution throughout the several layers, while in others a definite difference was noticeable between the upper and lower layers. According to them (Juday et al l. c.) these lakes could be classified under "seepage" lakes as the differences between the surface and bottom values were not so great as in the case, of the " drainage " lakes. They also found that the surface layers in drainage lakes had larger quantity of carbonates than the bottom layers. It must, however, be pointed out that in the case of shallow lakes (6-13 m) the carbonates were uniformly distributed from the top to the bottom. This was due to the mixing effect of wind action.

(c) *Distribution of carbondioxide, bicarbonate and carbonate in tropical lakes*

Several tropical lakes have been studied by Ruttner (1931, a, b), Jenkinh (1932), Beadle (1932-34) and Worthington (1932) with regard to these factors. Ruttner (l.c.) found distinct stratification

of carbon dioxide in the lakes of the East Indies. He found that there was stratification in "free CO_2" and that it was essentially similar to what Birge and Juday found in the North American lakes and to what Bronstead and Wesenberg-Lund found in European waters. He found that it was absent or present only in extremely small quantities in the surface layers, but that it increased gradually in quantity downwards. The absence of free CO_2 in the surface layers was attributed to the assimilatory activity of the plankton algae, and the gradual increase of CO_2 in the thermocline and hypolimnion to respiration of the organisms there and to the decomposition of organic matter. A close relationship was found to exist between their bicarbonate content and the geological character of their drainage basin. In most of the lakes, the bicarbonate content was found to be greater in the hypolimnion. The increase was attributed, just as in the case of temperate lakes, to the dissolution of the precipitated calcium carbonate by the accumulated free CO_2 present in the hypolimnion.

Beadle (l.c. p. 200) has found the alkalinity of the water of the lake Edward for example to increase from the surface downwards to about 70 metres or so, though there was practically no change in the alkalinity below that range.

(d) *Red Hills Lake*

In the case of the Red Hills Lake the vertical distribution of carbonates and bicarbonates was not the same in each month; its character though varying from month to month was not specially distinguishable for each period of the year. They were found either to decrease or increase or homogeneously distributed from the surface to the bottom or were present in larger amounts in the intermediate layers than those of the surface or bottom. This variation in the character of their vertical distribution is probably to be ascribed to the shallowness and the meteorological conditions prevailing in the lake.

(e) *Relation between the vertical distribution of carbonates and bicarbonates and the vertical thermal changes in the Red Hills Lake.*

A definite relation has been established between the vertical distribution of carbonates and bicarbonates and the vertical changes in temperature of temperate lakes (Birge and Juday l.c., Juday et al l.c.) and of tropical lakes (Ruttner l.c., Beadle l.c.) during the summer months. " The character of the vertical distribution is dependent to a large extent upon the thermal stratification which in turn depends chiefly upon the depth and area of the lake" (Juday et al p. 23 l.c.). In the case of the Red Hills Lake, a temporary thermal stratification is formed in the afternoon but this is not always accompanied by a gradual decrease of the carbonates and an increase of the bicarbonates from the surface downwards, as in the case of the temperate and tropical lakes cited above. The carbonates were found to increase or to decrease from the surface to the bottom or were found homogeneously distributed throughout from the surface to the bottom. Therefore, both the carbonates and bicarbonates do not exactly follow the thermal changes in the water. Similar cases have also been reported in temperate lakes. Juday et al (l.c.) themselves found in certain lakes a uniform distribution of bound carbondioxide e.g. in Beak Lake which is very shallow and so did not show any thermal stratification. On the other hand, they found the same to be the case even in crystal lake which is deep enough to be thermally stratified.

As regards the bicarbonates they found that (i) they were not uniformly distributed from the surface to the bottom in lakes of 6 m depth; (ii) they were found to increase near the bottom in lakes of 6 to 13 m depth, which showed a slight thermal stratification *e.g.*, Dorothy Dunn lake; (iii) a large variation of the lower water was found in lakes ranging from 15 to 20 m in depth, *e.g.*, Carr and Crystal lakes; (iv) a smaller amount in the thermocline than either above or below this stratum, *e.g.*, Anderson, Paliette, and Silver lakes. These decreases in CO_2 content of the water in the thermocline were due to the photosynthetic activities of the phytoplankton of this stratum.

All the four types of vertical distribution cited by Juday et al in the different lakes of the north-eastern Wisconsin have been recorded by me in the Red Hills Lake during the different seasons of 1934 and 1935.

Taking all the three items, free CO_2, bicarbonates and carbonates in the Red Hills Lake, there does not appear to be any relationship between these and of the thermal stratification when that is most pronounced.

Juday et al (1935, p. 6) found that the surface water was alkaline to phenolphthalein in all the " drainage " lakes investigated by them. They state " This alkaline reaction to phenolphthalein was due to photosynthetic activities of the various aquatic plants, chiefly to phytoplankton forms; these organisms removed some of the half-bound carbondioxide from the bicarbonates during process of assimilation, thus leaving a certain amount of normal carbonate in the water, which gave it an alkaline reaction." The lake under investigation (the Red Hills lake) is a " drainage " lake. It is very interesting to find that in this lake also the surface waters are alkaline to phenolphthalein at all seasons.

(vi) Temperature, Bright Sunshine, Wind Surface Area, Depth and pH.

From a study of the literature available on the subject, it is found that natural waters show a wide range in pH from pH 1·4 to 12·0. " Jewell and Brown (1929) obtained readings of pH 3·3 on the waters of pools in the Sphagnum Margin of Michigan bog lake and Skadowsky (1926) reported readings pH 3·4—3·8 for waters of some Russian bogs. Strom (1925) reported readings as low as pH 3·8 in the waters of peaty bogs of Norway. Yoshimura (1933) obtained a reading of pH 1·4 in a Japanese lake which received water from a volcanic region and the sulphate content of the lake water was 174 mg./l," (Juday et al 1935). Ueno (1934) has reported a pH value of 3·0 for a brook in North Shinano, Japan, which contained a large quantity of sulphuric acid.

All these records have been made on the water of temperate lakes only.

As regards the pH values recorded so far for tropical waters the pH values of the South African lakes range from a minimum of 3·7 to a maximum of 9·8 (Hutchinson et al 1932). Jenkins (1932, p. 547) has recorded values ranging from pH 8·3 in lake Naivasha to pH 12 in the lake Nakuru of the Rift Valleys in Kenya. Hem Singh Pruthi (1933) obtained a range of 7·4—9·0 for the pond water in the Calcutta museum.

A study of the seasonal and vertical changes in the pH values of the Red Hills lake shows that the lake water is definitely alkaline, the range varying between 8·4 to 8·9. In 1933 alone the lower limit reached was 7·7 due to heavy rainfall (Welch 1935, p. 114). Among the tropical lakes in this respect, it resembles the lakes of East Indies which have been stated to be definitely alkaline and above pH 8·0 (Ruttner l.c.).

(*a*) *Stratification in pH*

A few recorded instances of pH stratification in tropical lakes is given below:—Graham (1929, cited by Ruttner 1931) found in the Lake Victoria significant differences between the surface (8·5) and the bottom (7·4). In the lakes of Java, Sumatra and Bali, Ruttner (l.c.) found that the pH values of the surface water in almost all lakes was above pH 8·0 and those of the bottom layers varied from pH 7·2—7·4, showing distinct stratification.

Uniformity in pH values in all the layers (pH=6·8) was observed only in Danu Bratan in Bali by Ruttner (l.c.). This condition was attributed by him to complete overturning and circulation.

In the case of the Red Hills lake, uniformity in pH values was noticed from the surface to the bottom in all the months during 1934 and 1935, although on all these occasions a very weakly expressed thermal, and oxygen stratification was present. This might appear rather strange, for in almost all cases where thermal and chemical stratification (in O_2 and bicarbonates) have been reported, stratification in pH values also have been recorded. For example, in Plonersee, Wiebe (1931), Juday et al (1935) in Wisconsin lakes have found thermal stratification always being accompanied by chemical stratification also (in O_2, bicarbonates, pH etc.). In the latter case, the differences have varied from 0·2 to 2·8 pH units. (Juday et al l.c.). So, the absence of such a phenomenon in the lake under investigation is most probably due to very small differences (less than 0·2 unit) in the values which cannot be easily determined with the help of the Hellige comparator used in these studies. Gessner (1932) has come to a similar conclusion when using the Hellige comparator for pH estimations.

(b) *Diurnal variations in pH values*

Diurnal variations in the pH values of the surface water in lakes have also been recorded. A difference of 2·6 units (Skadowsky, l.c., cited by Juday et al 1935) was noted in some of the surface waters of lakes near Moscow, and of 2·45 units (Philips, l.c. cited by Juday et al 1935). Butcher et al (1930) found the pH values to be minimum during the hours of darkness and maximum at the time of the maximum oxygen content. Birge Juday (1911) on the other hand found no diurnal variation in Lake Mendota. Worthington (1930) found a change from 7·95 to 8·7 in the Lake Victoria; and Pruthi (1933) from 7·8 to 9·05 units in the Museum pond, Calcutta. The latter found that it was low in the morning and maximum in the afternoon, and had decreased after 5 P.M. He has also stated that this diurnal difference was "bigger" than that recorded so far in the case of any tropical water. He has stated further that the diurnal changes in pH of temperate waters is much less. But this appears to be incorrect according to Skadowsky and Philips, cited above. Variations in pH on the same day are noticed usually in ponds and pools which are fully protected and which contain plenty of aquatic vegetation, but in the larger bodies of water, they cannot be so easily detected (Welch 1935, p. 114). The latter's observations appear to be confirmed in the case of the Red Hills lake. Though observations on diurnal changes in pH values were not made, they have been made at different times of the day on different dates in different months and in one case in the same month. Thus, the pH value of the surface water at 6·14 A.M. on 3-4-34 and at 1·0 P.M. on 29-4-34 was 8·3 (Table XII, Ganapati 1934) showing that there was practically no diurnal changes in pH. This conclusion is also supported by Beadle (1932-34, pp. 179 & 188) who found in Lake Baringo a change of 0·1 only from 6-30 A.M. (8·7) to 12-30 P.M. (8·8 pH); and 0·2 unit only from 12 midnight (9·4) to 12 midday (9·6) in Lake Rudolf. Or it might be due to the apparatus, used, as has been stated previously.

(c) *A Brief Review of the Factors influencing pH*

The important factors which regulate the reaction of natural waters are (i) CO_2, (ii) carbonates of calcium, magnesium, sodium and potassium, (iii) salts of strong acids and weak bases, and (iv) humic acids.

(i) *Carbonic acid.*—Carbonic acid is a weak acid and its mode of formation has been explained already. Its quantity is responsible to a large extent for the changes in the chemical condition of the water. These changes are brought about by the withdrawal of CO_2 by various causes mentioned before. So, the effect of CO_2 upon the pH value of natural waters is to increase or decrease the value. Neresheimer and Ruttner (1929), Wiebe (1931), Maucha (1929) and Schutow (1926)—all cited by Juday et al (1935) have shown that if both free CO_2 and bicarbonates are entirely used up, the assimilation does not stop at least with the higher water plants as they use "bound" CO_2 or monocarbonates. Above a pH value of 8·0 there can exist no "free" CO_2 in water (Smith).

In the case of the Red Hills Lake, free CO_2 has not been detected excepting on one ocassion i.e. on 23-12-33. The presence of free CO_2 is attributed to heavy rainfall in that month, so that the pH value also was as low as 7·7. On all other occasions, when free CO_2 was absent, the pH values were higher and ranged from 8·4—8·9. Its absence indicates that either it is used up as soon as it is formed or the amount that is regenerated is not sufficient to convert all the monocarbonates into bicarbonates. So, "free" CO_2 by itself does not seem to be an important factor in influencing the reaction of the Red Hills Lake water.

(ii) *Carbonates of calcium, magnesium, sodium and potassium*:—Calcium carbonate in the form of pure calcite gives a limiting value of pH = 9·0. Atkins (1919-22), Moore et al (1921) have shown that sea water may become as alkaline as pH = 9·7 as a result of very active photosynthesis. This is due to the presence of magnesium salts since the limiting pH value of magnesium carbonate is 10·0, the same as for $Mg(OH)_2$. Values between 10 and 12 obtained with the lake waters such as those situated in the Rift Valley in East Africa are due to the presence of sodium carbonate derived from the volcanic rocks of their respective drainage basins (Jenkins 1932, Beadle 1932-34).

In the case of the Red Hills lake, the pH values range generally from 8·4—8·9. This indicates therefore the presence of the salts of calcium in greater amounts than those of magnesium; sodium, and potassium are present in the Red Hills lake water. This conclusion is further borne out by the results contained in Table No. XI Ganapati (1934, 1935).

(iii) *Salts of strong acids and weak bases*:—For those lake waters in which the pH value is less than 6·0, the presence of strongly dissociated acids or salts of strong acids and weak bases with small amounts of buffer salts or humic acids is indicated Hagland (1912 cited by Lonnerblad 1931) and Schaperclaus (1926) have attributed the low pH values to the presence of free sulphuric acid in the waters examined by them. Strom has obtained values lower than 4·0 for Norwegean waters and attributed the figures to the presence of humic acids (cited by Lonnerblad 1931). Yoshimura (l.c.) and Ueno (l.c.) have obtained pH values of 1·4 and 3·0 respectively and have attributed the low figures to the contamination of these waters with sulphuric acid. "Water in the outlet of a thermal spring in Japan has been reported to have a pH of 2·2" (Welch 1935). "In general however, readings below pH 4·0 are not found in natural waters except under extreme bog conditions or in cases of pollution with mineral acids" (Juday et al 1935).

Red Hills lake water is not contaminated with waters containing strong acids like sulphuric acid, and therefore is always distinctly alkaline.

(iv) *Effect of Humic acids*:—Most bog lakes are acid in reaction due to the presence of humic acids, and Oden (1922) has established a pH value of 4·5 for this effect. So humic acids are absent in Red Hills lake.

Relation between the vertical changes in pH and the thermal changes in the Red Hills Lake

Usually in all temperate lakes in the summer months, when there is thermal stratification, it is always followed by stratification in chemical conditions such as dissolved oxygen, carbonic acid, pH etc. A few examples in support of this are the Wisconsin lakes of United States, Central European lakes etc.

In the case of tropical lakes also, a similar relationship has been recorded. Jenkins (1932, p. 457) found in Lake Nakuru a fall in pH from the surface (12·0) to a depth of 1·75 m (10·1); Beadle (1932-34) found in Crescent Lake at midday a fall of 1·3 pH units from the surface (9·1) to a depth of 18 metres (7·8) on 23-11-30; and a fall of 0·1 unit from the surface (8·5) to the same depth (8·4) on 26-2-31. Ruttner (l.c.) also has recorded similar relationship in the lakes of East Indies. Worthington (1930, p. 336-337) found a stratification in pH which was dependent upon the thermal stratification in the Kairrondo gulf in the Lake Victoria. The pH value of the surface water was found to rise from the morning till the afternoon and to decrease after 3 p.m. till next morning corresponding to the rise and fall in the case of temperature. Worthington and Ricardo (1936) found an intimate relationship between the temperature and pH values in the deeper portions of the East African lakes. The temperature and pH values showed temporary stratification upto a depth of about five metres by midday and mixing till that depth only by night.

In the case of the Red Hills Lake, there is a temporary thermal stratification by the afternoon, but it is not accompanied by definite changes in pH. This might probably be due to the shallowness and vast surface area of the lake, which prevents the development of a thermocline.

Classification of the Red Hills Lake based upon its pH values.

Birge and Juday (1911) consider lake waters acid if they contain more carbonic acid than is necessary to convert the carbonates into bicarbonates. But waters which are acid to phenolphthalein show an alkaline reaction with methyl orange. Discrepancies of this kind have been removed by the use of the more exact methods which have been recently introduced for determining the hydrogen ion concentration of water. pH values of lake waters have been used as basis for classification of lakes. Wehrle (1927) divided lakes and ponds into four groups:—(i) those with very acid waters which are buffered by salts of humic acids; (ii) those with moderately acid waters, weakly or not at all buffered; (iii) those waters showing in summer a diurnal variation between an alkaline and a moderately acid reaction; and (iv) those with a permanently alkaline reaction. According to the above classification, the Red Hills Lake will come under the fourth group of Wehrle's as its water is permanently alkaline (pH 8·4-8·9).

Fritsch (l.c.) has briefly summarised the relation between hydrogen ion concentration and the chief types of water as observed by other workers as follows:—"Naumann (89, p. 302) emphasises that neither in oligotrophic nor in eutrophic lakes are any marked extremes of hydorgen ion concentration to be observed, so that the conditions admit of the development of a large diversity of organisms, and other factors than pH determine the quality of the phytoplankton (and no doubt of the algal flora generally). In eutrophic lakes, however, there is a marked difference of pH between the upper and lower layers of water (12, p. 34). According to Skadowsky (124, p. 114) also the pH is very constant in deep lakes with hard waters and in acid waters. He points out that in eutrophic waters the variations in pH are the greater, the smaller the concentration of dissolved salts and the shallower they are, and both he and Naumann (89, p.302) ascribe this to the high plankton productivity. The influence of the latter on the reaction of the latter type evidently varies with its nature, the highest degree of alklinity being produced by a Myxophyceous plankton." In the Red Hills Lake also which approaches the eutrophic type of lake marked extremes of hydrogen ion concentration are not noted as the range is only between 8·4 and 8·9. But, unlike the eutrophic type of lakes referred to by Fritsch, in the Red Hills Lake, there is no difference between the surface and the bottom layers since no stratification in pH value is seen.

Juday et al (1935, p. 5 & 47) classify lakes of the North-eastern Wisconsin into two groups: "seepage" and "Drainage". Seepage lakes are "those bodies of water which have temporary or permanent outlets." They state that "the seepage lakes, in general, contain a smaller amount of dissolved inorganic substances which will serve as buffers than the drainage lakes, and that this produces a characteristic difference between the two types with respect to their hydrogen ion. Their pH results show the characteristic difference between the two types of lakes. Generally speaking, the pH values of the surface waters of the majority of the seepage lakes range from 4·4 to 6·5; while those of the drainage lakes range from 6·6—8·9 (Juday et al, 1935 p. 47).

In the case of the Red Hills Lake, which constitutes an intermediate type in as much as it has got both an inlet and several outlets all through the year, the pH values (8·4—8·9) of the surface water approach those of the "drainage" type referred to above.

(vii) Rainfall, Temperature, Geological Character of the Catchment Area, Depth and Phosphates (P_2O_5)

The major portion of the phosphates found in fresh waters is derived by the leaching action of chemicals from the surrounding land after each rainfall. A small portion is also obtained from the decay of plants and animals.

They occur only in very small quantities and are found in two states. (i) organic and (2) inorganic. In the former case, the phosphorous is found in combination with the organic materials in the water such as the dead material of the plankton and other organic debris, and " a certain part of it may consist of dissolved phosphorous that is *not in a pentavalent state* " (Juday et al 1927). In the latter case, it is found commonly as phosphates of sodium, potassium and ammonium and their double salts (Kenwood 1930). These salts are in a state of solution and are readily available for plants in the water. A certain portion of this is usually lost from the main body of the water by being absorbed by the bottom deposits (Black 1929).

It is very interesting to note that though the water of the Red Hills Lake was examined for phosphates every month during a period of two years, on not even a single occasion phosphates were found at any portion of the lake.

The experience of other workers with the temperate and tropical waters has been found to be as follows: Some have established a seasonal variation in the quantity of phosphorous while others have not found any such correlation.

Range of variation in temperate lakes.

MacHargue and Peter (1921, cited by Juday et al 1927) found that the soluble phosphate content varied in the springs, streams and rivers of U.S.A., and that it depended upon the nature of the geological strata. Clark (1924) found that it varied from a mere trace to 0·133 mg/1 in the river and lake waters of the U.S.A. Atkins (1923-1925b) found in the natural waters and reservoirs of England, Scotland, extremely small quantities of soluble phosphates (less than 0·05 mg/1) and that anything above 0·5 mg/1 was indicative of sewage pollution.

Brandt (1919, cited by Wiebe 1930) found in the North Sea the smallest quantity in May and June, and the greatest in November and February and that the quantity ranged from 0·029 to 0·070 mg/1 in the surface water. Atkins (1927), Marshall and Orr (1930) established a correlation between the increase in phytoplankton and the decrease in phosphate. Atkins (1923-1925b) found that the waters of tropical seas were very poor in phosphates and attributed their deficiency to the greater amount of sunlight available and the consequent increased assimilatory and metabolic activity on the part of the plant plankton organisms both in summer and winter. Atkins and Haris (1924) have concluded that the consumption of the soluble phosphates in the early spring limits further growth.

The quantitative studies of Juday et al (1927) and by Juday and Birge (1931) in the lake waters of Wisconsin did not give any positive evidence that it was a limiting factor in the production of phytoplankton. Wimmer (1929), Tressler and Domogala (1931) also have arrived at a similar conclusion.

As regards *tropical lakes,* Ruttner's work on the East Indian lakes stands foremost. He found that the inorganic P was greater than in the North-American lakes, and that it varied from 0—0·02 mg/1 in the surface layers. Beadle (1932-34) found greater quantities of phosphates in the East African lakes than those of the East Indies. Carter and Beadle (1930-32) have stated from their studies of Paraguayan swamps that seasonal variation of the type noted by Atkins was strikingly absent but that they thought that the absence of such a seasonal variation was probably due to the high concentration of the phosphates. The reduction of the phosphate content as the swamp water evaporated was also probably due to its having been used by the phytoplankton. Hutchinson et al (1932) found that the amount of phosphate varied from a minimum of 0·01 mg/1 to a maximum of 6 mg/1 in the South African pans and other inland waters.

Though conflicting views have been expressed regarding the role of phosphates in controlling the phytoplankton, the important part it plays for aquatic vegetation cannot be doubted.

Reasons for the absence of phosphates in the Red Hills Lake.

It has been stated in the beginning of this section that one of the sources of phosphates for lake waters is by the leaching action of chemicals from the surrounding land after each rainfall. But in the case of the Red Hills Lake, the drainage basin is not likely to

be an important source, as the soil is laterite and as such cannot materially add to the phosphate content of the lake water after each rainfall. So, the chief sources must be from within the lake or from the Sholavaram lake, which drains into it or both. But phosphates have not been found at any time. Their absence is most probably due to their utilisation by the phytoplankton as soon as they are formed. They are most probably continuously regenerated and are continuously consumed by the phytoplankton. Their absence at any depth is also due probably to the diurnal mixing of the several layers. Waksman et al (1937, p. 371) have reported that "In the presence of an adequate supply of available energy, all of the phosphate originally found in the sea water and also that amount which was liberated in the decomposition of the diatoms was consumed by the rapidly multiplying bacteria. But in turn it was soon regenerated into the sea water as the bacteria died and underwent autolysis." Therefore, it may be reasonable to suppose that a similar situation as in the case of the sea exists in the Red Hills Lake also. If that should be so, then the phosphates are utilised by the plants first, then during the decomposition of the latter by bacteria are probably consumed by them; and finally after their death liberated into the water, to be used up again by the plants. This cycle is probably taking place throughout the entire body of water and at all seasons in the lake, so that phosphates are not detected at any time. This conclusion is in perfect agreement with the finding of Ruttner (1931, pp. 436-438) who found only traces or none of phosphates in most of the lakes of the East Indies. This is also to be attributed to the longer hours of bright sunshine resulting in more active and longer assimilation period every day than in the temperate region.

(viii) Rainfall, Temperature, Bright Sunshine, Geological Character of the Catchment Area, Surface Area, Depth and Silicates (SiO_2)

Just as in the case of phosphates, the amount of rain water draining into a lake from its catchment area is an important source besides that brought in by feeder rivers and streams. They are also dissolved from the bottom sediments in a lake. They appear chiefly as salts of silicic acid of sodium and potassium in solution and sometimes in colloidal solution.

(*a*) *A general account of the vertical distribution of silicates so far recorded in the temperate and tropical lakes.*—Birge and Juday (1911) found a direct relation between the amount of silica dissolved in the upper layers and the diatom growth. In Lake Wingra, the correlation between the two was not so marked (Tresler and Domogalla 1931). Atkins and Harris (1924) have shown that the content of silicates of fresh waters varies with rainfall and that an increase of temperature and alkalinity favour the solution of silicates in suspension. Pearsall (1923b) has stated "The presence of considerable amounts of organic matter is understood to imply the appearance of large proportions of dissolved silica, though the connection if any is not understood." Yoshimura (1930) found in 10 waters of Japan a variation of 3·3 to 57·5 mg/l and in most cases it was found to increase with depth.

(b) *Tropical Lakes.*—A maximum value of 41—69 mg/l was obtained by Jenkins (1932) for the water of the Lake Naivasha in June 1929. Beadle (1932-34) found an apparent decrease of silicates with an increase of alkalinity in the Rift Valley lakes of East Africa. This is apparently a contradiction to what has been observed in the case of the temperate lakes (Atkins and Harris l.c.) But Beadle attributes his observation to errors in the existing technique for the estimation of silicates in the highly alkaline waters of the type he has met with in East Africa.

The experience of Ruttner (1931) was different in the case of the lakes of East Indies. He found it to vary from a minimum of 1 mg/l in Danu Bratan to a maximum of 97 mg/l in Ranu Klindungen. In the latter lake, he found the silicate content to increase with depth. In Tjigambong he found the silicates to decrease with depth, and in the lakes Bratan, Batur, and Toba to be nearly homogeneously distributed.

In the South African pans and lakes, Hutchinson et al (1932) found the silicates to vary from a minimum of less than 1 mg/l to a maximum of 30 mg/l.

(c) *Red Hills Lake.*—The silicate content is not so great as that recorded for the highly alkaline lakes of East Africa. But it resembles the values recorded for those of Lake Toba North (Ruttner l.c.)

As regards the vertical distribution, three types have been recorded during the course of a year; (i) uniform distribution from the top to the bottom as in Danu Bratan (Ruttner l.c.) (ii) increasing with depth as in Ranu Klindungen (Ruttner l.c. and Yoshimura l.c.) or decreasing with depth as in Tjigombong (Ruttner l.c.)

There was no general correlation of silicates with temperature or season or with depth in the Red Hills Lake.

(ix) Rainfall, Temperature, Bright Sunshine, Geological Character of the Catchment Area, Surface Area, Depth and Nitrogenous Compounds.

Lakes obtain their nitrogenous substances from rivers or streams flowing into them, more from their catchment area if it is composed of inhabited and agricultural lands than from a wild unsettled area, from the decomposition of organic material and excretions of aquatic animals. They occur in varying amounts in different waters and also vary with the seasons, the amount of pollution and the abundance of plankton life. They occur in two forms: organic and inorganic. *Organic nitrogen* is found partly in suspension and partly in solution. *Suspended organic nitrogen* is that which is found in the millions of bacterial cells, in the phyto-and zoo-plankton and other floating organic materials in water. These can be easily separated from water by filtration or centrifuging. The soluble organic nitrogen (in true and colloidal solution) results from the decomposition of dead organic matter by bacterial action; and from excretions of aquatic animals.

The inorganic form of nitrogen consists of ammonium salts, nitrites and nitrates. Free ammonia or ammonium salts result from the decomposition of organic matter by saprophytic bacteria and from free ammonia and ammonium salts result nitrites, and then nitrates by the action of nitrifying bacteria. Free nitrogen and ammonia can be formed by the action of denitrifying bacteria on nitrites and nitrates. Therefore the total quantity of inorganic nitrogenous compounds will be dependent upon the proportion of nitrifying to those of denitrifying bacteria.

(a) *Distribution of nitrogenous substances in temperate lakes.*—Very valuable work has been done upon the Wisconsin lakes by Peterson et al (1925), Domogalla et al (1925, 1926). They estimated quantitatively twelve different forms of nitrogen; and established a seasonal variation in their quantities. Tressler and Domogalla (1931) found that the ammoniacal nitrogen followed the nitrate nitrogen in a general way; the latter was higher in winter than in summer, and was also found to vary inversely with organic nitrogen. Organic nitrogen was found in maximum in spring and summer when vegetation was abundant. In other Wisconsin lakes nitrites and nitrates were found in traces or were absent completely (Progress Biol. Inq. 1926).

Pearsall (1921a) has correlated the nitrate content of lake waters with the nature of their drainage basins. He found that in the case of the English lakes, those with rocky drainage systems and shores have relatively low nitrate maxima and the other lakes which have a greater proportion of soil on their basins have higher nitrate maxima. He concluded therefore that the nature of the drainage systems plays an important role in developing the nitrogen reserve in lakes.

(b) *Distribution of nitrogenous compounds in tropical lakes.*—As regards ammoniacal nitrogen, Ruttner (1931) found that it was present in largest amounts at the bottom layers but that it gradually decreased upwards and was almost completely absent in the surface layers of deep lakes.

As regards the records for the presence of nitrites and nitrates in the tropics very little is known. Hutchinson et al (1932) state that nitrites were found in traces in all the pans and lakes of South Africa. Beadle (1932-34) found traces or nil of nitrites and nitrates in the Rift Valley lakes of East Africa.

(c) *Red Hills Lake.*—In the case of the Red Hills Lake, albuminoid nitrogen alone was found to show seasonal variations as in temperate lakes. It was found to be higher in the hot weather and south-west monsoon seasons than in the north-east monsoon or cold weather periods. This finding is in agreement with that of Tressler and Domogalla (loc. cit.)

As regards the other three forms of nitrogen, while in all temperate lakes they have either been found in varying amounts in the different seasons or to be found in traces or absent, it is rather surprising to find only traces of ammoniacal nitrogen and a total absence of nitrites and nitrates in this case. The lake is a very shallow one and the phytoplankton is fairly evenly distributed from the surface to the bottom layers. The phytoplankton readily utilised any available nitrogen that may be present in the water. This process probably takes place during their photosynthesis which must naturally be very active owing to the strong tropical illumination and also its longer duration in the tropics (Atkins 1932-33).

In the deeper tropical lakes such as those of Sumatra, Java and Bali investigated by Ruttner (l.c.) the amount of ammoniacal nitrogen increases downwards—probably on account of the deeper layers not receiving as much illumination as the upper layers and the consequently less photosynthetic activity. Again the quantity of phytoplankton also decreases downwards according to this author (Ruttner 1931 b), meaning thereby less photosynthetic activity there. These facts are probably responsible for the nitrogenous

compounds being utilised in the upper more illuminated layers and being less utilised in the deeper and less illuminated layers.

A second factor may possibly also be at work. It is just possible that the absence of nitrites and nitrates is due to the activity of the denitrifying bacteria. The studies of Drew, Macclendon (cited by Pia 1934), Atkins (1926-27), Harvey (1926, '28) and Cooper (1937) for sea water show that denitrifying bacteria thrive more richly in the warm seas than in the cold seas. These bacteria are very active at higher temperatures (27°—30°C) or slightly more but are not so active when the temperature is below 15°C (Pia 1934). The presence of nitrites and nitrates in the temperate waters is probably to be ascribed to the lower temperature of these waters and the consequent lesser activity of these denitrifying bacteria; whereas in the case of the Red Hills Lake, the temperature, even at the bottom rarely goes down below 27°C during any part of the year, which temperature is most favourable for the activity of these organisms. So any nitrites or nitrates that may be formed in the water will be immediately reduced by these organisms. Their absence in the Red Hills lake is in slight conformity with the finding of Beadle (l.c.) who has stated that they may sometimes be totally absent as in the Rift Valley lakes of East Africa.

(x) Rainfall, Temperature, Bright Sunshine, Wind, Character of the Catchment Area, Depth, Surface Area and Organic Matter

Organic matter in inland lakes is derived chiefly from phyto-and zoo-plankton, and to a smaller extent from higher plants growing in lakes and from washings of the surrounding soil after each rainfall.

Compared with other inland tropical lakes, the quantity of organic matter which is present in this lake water is considerably low. As has been stated above, organic matter is derived chiefly from the death and decay of phyto-and-zoo-plankton. The former depends upon nutrients salts like phosphates, and nitrates for their growth and multiplication. These salts are not present in the lake water. Probably they are present in traces and are utilised by the algae in presence of bright sunshine as soon as they are formed. But other factors such as temperature and sunshine are found in optimum without the nutrient salts of biological importance being found in fairly large quantities.

The absence of a reserve of these nutrient salts can be traced to the absence of a strongly expressed thermal stratification, which in turn is due to the shallowness and the vast area of the lake, which is unprotected on all sides against wind action.

Further, the character of the catchment area is such that no nutrient salts are likely to be washed into the lake after heavy rainfall during the north-east monsoon season.

Therefore, the productivity in the lake is comparatively limited. Still variations in its quantity are seen. The maximum quantity being found in August or September might be due to low level, concentration of water, and death and decay of vegetable matter due to smaller hours of bright sunshine; and the minimum in December or January might he due to dilution after heavy fall.

(xi) Rainfall, Temperature, Bright Sunshine, Character of the Catchment Area and the Bacteriological Conditions of the Lake Water.

Bacteria are usually washed into a lake after a heavy rainfall from the surrounding soil, and thus their numbers are increased. Further, if the margins of the lake are thickly populated, the lake water will be further polluted.

Most of the bacteria, especially the disease producing organisms easily succumb to high temperature and longer hours of bright sunshine which prevail in the tropics.

Therefore, we find the lake water to be of very poor quality during the north-east monsoon season and of fair quality during the hot weather and south-west monsoon periods, bacteriologically.

(xii) Rainfall, Temperature, Bright Sunshine, Wind, Character of the Catchment Area, Depth, Surface Area, and Phytoplankton

Free floating microscopic plant organisms or phytoplankton depend upon bright sunshine and upon the nature of substances dissolved in water for their nourishment. The lafter are obtained usually in two ways. They are obtained from the soil surrounding the lake after a heavy fall. They are also obtained from bottom sediments containing the highly complicated organic substances, which are first decomposed by bacteria into simpler substances and later on are converted into inorganic nutrient substances. They are formed in the hypolimnion during the period of thermal stratification (in summer, in the case of temperate lakes) and are brought to the surface during periods of "turn-over," when they are utilised by phytoplankton in presence of bright sunshine. In the absence of any thermal stratification, which is ordinarily prevented by vastness of surface area, shallow depth of the lake and wind action, the first source naturally attains greater significance.

Among the phytoplankton in any piece of water, three important groups of algae attain their maxima at one time or other. They are green algae, diatoms, and blue-green algae. The last group with which we are more concerned plays an important role in summer in shallow temperate lakes and its dominance is usually correlated with high organic matter, low nitrates, and phosphates (Pearsall 1921).

Fritsch (1907) considers this group as being the very characteristic organisms of tropical waters. Rich (1932, 1933) found that *Microcystis flos-aquae*, M. *aeruginosa*, and the genus *Aphanocapsa* were very common in East African lakes. Ruttner (1931 b.) found that the lakes of Java, Sumatra and Bali were characterised by the predominance of the smallest *Schizophyceae* (*Dactylocopsis*, *Anabaenopsis*, *Lyngbya*). Hutchinson et al (1932) found *Microcystis flos aquae* as the most important blue green alga in the larger waters and also in a variety of smaller habitats of South Africa. Beadle (1932-34) found *Microcystis* in abundance in lakes George, and Baringo, in smaller numbers in lake Edward, and little or none in lakes Naivasha and Rudolf. He found *Arthrospira* in plenty in Lake Hannington.

In the Red Hills lake, phytoplankton is not found in as great numbers as in our temple tanks. The two most dominant algae among them are *Aphanocapsa elachista var novo* and *Oscillatoria limnetica Lemm*, both belonging to the Myxophyceae group.

The chief factors favouring the development of blue green algae in the tropics are bright sunshine, high temperature of water, phosphates, nitrates and carbon dioxide. The first two are found in optimum while phosphates and nitrates are absent in the Red Hills lake. Their absence in the lake is probably responsible for the poor development of the algal flora as compared to those found in our temple tanks. Their absence is also due to the character of the catchment area and to the absence of a strongly expressed thermal stratification, which in turn is to be attributed to the shallowness and vast surface area of the lake.

SUMMARY AND CONCLUSION.

1. The most important problem of tropical limnology is the occurrence or absence of a stable thermal stratification. In the Red Hills lake, it is found that a weakly expressed thermal stratification is formed at all seasons at about midday; its duration is very brief and daily mixing of the surface and bottom layers seems to take place. In this respect, it resembles the Rift Valley lakes of East

Africa and differs from temperate lakes and those of Sumatra, Java and Bali.

2. The absence of a stable thermal stratification is due to meteorological and morphological features of the lake.

3. The absence of a stable thermal stratification is also indicated by the absence of a stable chemical stratification.

4. The presence in traces of free ammonia, and the absence of nitrites, nitrates and phosphates in the lake water are factors of great biological significance. Their absence is explained. The geological nature of the catchment area is such that it is composed essentially of iron oxide, silica and alumina. So, during the north-east monsoon season, when the lake is filled up with water from its own catchment area, the water is either free from phosphates and nitrates or contains them in such minimal amounts as to be used up immediately by algal denizens in the water, in presence of bright sunshine.

The absence of a stable thermal stratification of long duration prevents the regeneration and accumulation of free ammonia, nitrites, nitrates, phosphates and other substances of biological importance from the bottom deposits by bacterial action.

Also, the absence of nitrites and nitrates might show either that the free ammonia resulting from decomposition of organic matter even during the period of temporary thermal stratification, is utilised by phytoplankton before it reaches the stage of nitrates or that they are consumed by algae as soon as they are formed.

5. Therefore, the meterological, morphological and geological features—included broadly under the term "geographical"—appear to be responsible for low productivity in the lake.

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Topographical Surveys

BY

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There are different kinds of surveys, such as Marine Surveys, Land Surveys, Geological Surveys, Archaeological Surveys, etc. Land surveys only will be dealt with here. By land surveys is meant the surveys of the features on the earth's *surface*. Land surveys consist of two main branches :—"Topographical Surveys" and "Cadastral Surveys."

TOPOGRAPHICAL SURVEYS

Surveying is the process of accurately determining and recording the features on the earth's surface. Topography is the process of delineating these features in a map. Thus topographical surveying is the process of accurately determining and recording the natural and artificial features on the earth's surface and delineating them in a map. Natural features are rivers, hills, forests, lakes, etc., and artificial features are towns, roads, railways, and in short, whatever features are brought into existence on the earth's surface by human hands.

Only such features as can be legibly shown should be delineated in a map. Thus the amount of features that can be shown in a map depends upon the scale of the map and the nature of the country. In a small scale map—say 1 inch = 4 miles—only important details or features can be shown, whereas in a larger scale map—1 inch = 1 mile—more features can be shown. In a country where features are numerous, only such important ones as can be useful should be shown. The scale on which topographical surveys are carried out is generally 1 inch = 1 mile. Unless the surveys done and the maps prepared are accurate they are not only absolutely of no value but are misleading. Hence, for any work accuracy is most essential. For this purpose topographical surveys consist of two distinct process :—

(1) Triangulation or Trigonometrical Surveys to serve as framework, and

(2) Surveying and delineating the physical features on

the framework or the skeleton prepared on the basis of triangulation.

TRIANGULATION.

Triangulation is the process of covering the country with a net-work of triangles. Triangulation commences from a measured base and closes on another measured base. The process of triangulation as preliminary to topographical surveys was conceived only in 1735. The first country that was dealt with was South America and that by scientists from France and Belgium. It was only in 1745 the process began in England and it was not until 1792 it was completed. India was not far behind England in the commencement of such surveys. This work was started in India about 1800 and Madras was selected as a place to commence this operation as in the "Madras Observatory" observations for Longitudes and Latitudes were being taken since 1787 and calculated with reference to Greenwich; and thus it would be a proper fixed point to which the values—Longitude and Latitudes of the various triangulation points may be referred so that the map of India when prepared might occupy the place on the globe relative to the other countries. Thus the "Madras Observatory" is very important in the topographical survey of India.

Triangulation consists of three distinct branches:—

(1) Selection of sites for base lines,
(2) Construction of range of triangles, and
(3) Check on triangulation by astronomical observations for Latitude and Longitude.

As already stated triangulation was first commenced in Madras; and a flat place near Madras was selected for a base. This base runs north to south; the north end of the base is in the Race Course and the south end is on the Perumbakkam Hill. The length of the base is 7½ miles. The base is measured with absolute care with chain or steel tapes several times, and after applying corrections for sag, expansion due to temperature, alignment, slope, etc., the measurement is reduced to mean sea level and then utilised in the computation. The accuracy of the measurement of the base is of utmost importance as the measurements of the sides of the range of the triangles depend on this measurement.

Then points are selected for the construction of range of triangles. These points are generally on tops of hills, temple towers, church steeples and such eminent points so that large triangles may be obtained. Series of triangles are so formed and observations are taken at these points for angles, heights or depressions. The first series or range of triangles started from the Madras base and went westward to Bangalore and closed on a similarly measured base. This series was started by Col. Lambton. The series went up to west coast from Bangalore to Mangalore. Again another series started from Bangalore to Cape Comorin in the south and to Delhi in the north. These series are called Lambton's series. Several other series were also run along the coasts, parallel to and perpendicular to Delhi series, etc. Thus the whole of India was covered with a net work of triangles. Between these series several ranges of triangles were also run to cover the country fully.

Accuracy of the triangulation was checked at intervals by observations taken for Latitude and Longitude. For this purpose proper points in the series at intervals were selected and values of these points were computed direct from these observations and compared with those obtained by the solution of triangles—it must be remembered in passing that these triangles are spherical and not plane—starting from the measured base. Check is also exercised by comparing the measurement obtained by calculation of the base at the terminus of the series with that obtained by actual measurment of the base. For example, for the series from Madras to Bangalore, the length obtained by measurement of the base at Bangalore was compared with that obtained by the calculation of triangles.

As already said above, the Madras observatory was the starting fixed point for calculating the values of the various points fixed by triangulation. With reference to the values of this observatory the values of triangulation points were computed with a view to roject or plot them on paper to serve as framework for topograhical surveys.

For purposes of survey and issue of maps the whole of India ; divided into quarter degree sheets and degree sheets, the former eing on scale 1 inch = 1 mile and latter on 1 inch = 4 miles. 'opographical survey—field observation—is carried on 1 inch=1 ıile scale. Hence a skeleton or a framework showing the triangulaion points fixed at the trignometrical survey is prepared for each uarter degree on scale 1 inch=1 mile. It is mounted on a plane able head and taken to field for delineating the physical features n that part of the country.

The plane table is then set up on one of the fixed points and aligned in proper position by sighting other fixed points projected on the sheet. Then the magnetic meridian is marked by placing the magnetic compass on the table to indicate the magnetic north to facilitate the setting up of the table in other places.

Then the delineation of the features of the country round begins. To important physical features rays are drawn from the point after sighting them through the sight-vane. Temple towers in a village site or other prominent buildings, important bends along a road, or rivers etc., are generally sighted. Then the table is taken to another fixed point and another set of rays is struck to the same points. Thus the positions of these points are fixed by intersection and these are verified from a third fixed point. Thus the features are filled in by plane table survey minor details being sketched in by the eye.

Prismatic compass is also freely used in delineating the details. The whole sheet is thus filled in with details or features. The plane table surveyor should not only cover his sheet but also a portion of the sheets adjoining his so that there may be no difficulty in the combination of the sheets for a small scale map—say a degree sheet on 1″=4 miles. In the case of big lakes and forests the outer boundary is fixed by inter-section, interpolation, compass survey etc. In drawing the contours of hills, clinometer is generally used in ascertaining the heights at different points along the slopes; and contours are marked by a process called stepping, *i.e.*, by marking the intermediate points between two clinometer heights where the slope is roughly uniform. There are different methods of exhibiting the contours by joining the points of equal heights by continuous lines, by vertical hachures, by layers etc. Thus the whole sheet is completed in field and sent to office for further work of publication.

There was at first no printing office in India. Hence the original plane table sheets had to be sent to England for publication. Even in England there was no Government department for printing maps. The work had to be entrusted to private agencies. Aaron Smith brought out in 1822 his atlas of South India based on Lambton's triangulation on scale 1″=4 miles in 18 sheets from Krishna to Cape Comorin. The work of publishing the maps of the rest of India was entrusted to Mr. John walker who came of a family of engravers. For the purpose of publishing maps the whole of India, Burmah and Ceylon was divided into 177 sheets each sheet to measure 40 inches by 27 inches. It was not until 1868 that arrange-

ments were made to have the publication of maps done in India. By that time Mr. Walker had completed engraving of 84 sheets. Ever since, maps of India are being published systematically. Now degree sheets on scale 1″=4 miles and quarter degree sheets on scale 1″=1 mile are being issued and re-edited regularly by the Survey of India Department. In 1877 a very useful and valuable map of India on a scale of 64 miles to an inch was completed. Later on a general map of India on double the above scale was also published.

It may be of some interest to mention here that long before the publication of the map of India based on trigonometrical surveys, Major Rennell, the father of Indian Geography, brought out his famous map of India in 1788. This map was compiled mainly from route surveys carried out by the military staff at various times during the 18th century. When Bengal was acquired by Lord Clive Major Rennell began his survey of the Province and after completing that survey he returned to England and spent his time in bringing out his atlas of Bengal and his famous map of India. This is the starting point in the history of Indian Government map-making.

In conclusion it may be said that topographical surveys have very materially helped towards the completion of our knowledge of the physical geography of the vast tracts of India. The Indian topographical surveying by theodolite and plane table based on major and minor triangulation cannot be excelled for general accuracy and rapidity. These surveys on scale 1″=1 mile are very useful for engineering, military, administrative and geographical purposes.

Paddy Cultivation in Tinnevelly District

By

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Introduction.

The Tambraparni Valley is one of the best paddy growing areas of the Madras Presidency. There is a belt of rich fertile lands on either side of the river Tambraparni; and the average acre yield of paddy here is about 2000 lbs., the maximum out-turn recorded being 5200 lbs. The total area under paddy cultivation is somewhere in the neighbourhood of three lacs of acres representing about 20% of the cultivable area of this district and of this roughly two third area is irrigated by the perennial river Tambraparni and its tributaries and the remaining one third area, chiefly confined to the taluks of Nanguneri, Sankarancoil and Koilpatti, is irrigated by purely rainfed tanks, and jungle and mountain streams rising from the Western Ghats during the north-east monsoon.

Soil of the tract.

The Tambraparni valley may be broadly divided into three portions. 1. The upper or head portion. 2. The middle portion. 3. The tail end portion of the valley. The conformation of the land in this valley is undulating and the fields are well drained. The soil is a red sandy loam with an impervious substratum of gravel at a depth of 1′ to 1½′, especially in the higher regions of the valley; and hence these light open soils respond to manuring immediately with very good results and unless these fields are replenished with plant food year in and year out the fertility of the soil cannot be maintained at its high level. The middle portion ...tly of clayey loam with a very good capacity to retain mois... The lands at the tail end of the river are somewhat heavy loams with alkaline patches near the coastal region. The ...nds in the higher regions of this valley are all double crop ...nds as there is an early receipt and never-failing supply of ... but in the lower regions the lands are classified either as ... or compounded double crop lands because the supply of

water is not always assured. But there is a bright future for this valley when the construction of the Papanasam-Reservoir is completed. Though it is mainly intended for generating hydro-electric power, it may no doubt go a long way in augmenting and supplementing the supply of irrigation water during years of subnormal rainfall and thus averting the catastrophe of complete failure of paddy crops in the valley.

Rainfall and paddy season.

The average rainfall of this valley is about 40 inches and the paddy season commences with the advent of the south-west monsoon which usually breaks out late in the month of May or in early June. When the monsoonic symptoms are signalled in the Western Ghats where the river Tambraparni and its tributaries rise, the ryots start their kar nurseries well in advance with the help of water from wells or ponds nearby. The south-west monsoon on an average records about 5 to 6 inches of rain and the freshes received in the river from the month of June facilitate the kar cropping. Dogging at the heels of the south-west monsoon, the north-east monsoon sets in from the middle of October and extends upto the end of December and brings in its train heavy rains, ample enough to fill up the rainfed tanks, and facilitate the semi-dry paddy cultivation in normal years. The north-east monsoon precipitates about 20″ to 25″ of rain and it is in this period the main paddy crop is taken in the single crop wet lands of this district and it synchronizes with this pishanam or 2nd cropping of the Tambraparni valley. Thus there are two well defined cropping seasons for paddy in this tract namely—kar season (June to September) and pishanam season (September-March) besides the Manavari season (December-March) in which a manavari crop which is chiefly confined to the tracts where the supply of water is conditioned by the vagaries of the north-east monsoon.

The hot weather period, January—April records about 4 to 6 inches of rain and the summer showers during the period are often helpful to the ryots to take a cash crop like senna or gingelly or blackgram especially in the single crop wet lands. In the upper regions of the valley with the aid of summer rains, the wet lands are brought to a fine tilth for broadcasting kar seeds.

As a whole, the fairly even distribution of the average rainfall of 25 to 30 inches of rain in the main paddy season (September to February) may be considered sufficient to raise a good crop of paddy.

Cultivation Routine—Kar Season.

The varieties grown during the kar or first crop season are of short duration ranging in age from 110 to 120 days. The main variety that rules over the whole area of the Tambraparni valley is Kar-samba red; and some of the other varieties grown are kar-samba white, vari-samba and Katti-Samba. As a rule, transplanting is always adopted. But in the upper regions, broadcasting is done in the light type of soils when the lands have been brought to a fine tilth fit for broadcasting with the help of summer shower ploughings. It may be recorded here that it is the experience of the ryots that the yield of a timely broadcasted crop gives a better out-turn than the transplanted crop and so for the light types of soil, that is, sandy red loams the summer ploughings are not found to be injurious to the succeeding paddy crop. This finding, however, should be tested and confirmed by conducting regular cultural experiments. The kar nurseries are generally dry ploughed with the help of summer showers and kept in a fine tilth and the seeds are sown in dry seed beds in June at the receipt of water in the Channel or earlier with the help of water from ponds nearby or with the soaking showers received in the latter half of May.

Preliminary Cultivation.

After the harvest of the Pishanam crop, the fields are ploughed dry, when the lands come to condition. If this opportunity is lost for some reason or other, the lands are wetted in March before the channels are closed and then ploughed when fit for dry ploughing. Subsequent ploughings are given to the fields as many times as possible at the receipt of summer showers in April and May. Generally in normal years, 9 to 12 ploughings with the country plough are given to the fields and brought to a fine tilth for the Kar crop.

Planting.

Should the tilth of the fields to be transplanted be in a very good condition, water is let into the fields and the planting is done straight away by women with seedlings 25 to 30 days old lifted from the dry nurseries previously kept ready without giving any further wet ploughings to the fields. But if the conditions of the fields are not good, 2 or 4 ploughings are given with the country plough, levelled and immediately transplanted, lest the soil should get hardened. The former method is largely practised as it saves lot of time and labour during the busy transplanting season. The ploughings given to the field are very shallow, the depth being 2 to 3 inches and so the use of the iron ploughs like cooper No. 25 or

11 for the light and porous nature of soils especially should be strongly advocated as it is not only beneficial but also more economical. Two ploughings with iron ploughs followed by the working of the puddling implement devised by the Agricultural Research Engineer twice or thrice bring the soil to a fit condition for transplanting. The puddler brings the clods, making the particles into as fine a condition as possible so that the irrigation water will not drain down too rapidly and thus it facilitates to prepare the wet land into an ideal condition for the paddy crop. The puddler can be worked by a normal sized pair of animals and it can cover 2 to 3 acres in a day of eight hours working. By this improved method a ryot can easily save a rupee for an acre in getting his lands prepared for transplantation.—usually for pulling out seedlings and transplanting an acre about 20 women are required. The practice is bunch planting, about 6 to 9 seedlings even per hole, distanced 6 to 9 inches apart either way. It may be noted that the optimum spacing that can be adopted for kar crop is about 4 to 6 inches with two or three seedlings per hole.

Pishanam season.

In the Pishanam season a long duration fine variety like Anaikomban 160 days from the date of sowing to harvest is usually grown. Some of the other second crop varieties cultivated are Sendhinayagam, Sembuli, Milagi and Arikiravi.

Soon after the harvest of the kar crop in the last week of September, the fields are ploughed and kept in a puddled condition fairly over a month or so as the consensus of the ryots' opinion is that a well rotten puddle for the pishanam crop is very conducive to its vigorous growth. Generally 6 ploughings with the country plough are given to make the kar stubbles rot well. It is here also the puddling implement is immensely useful as it serves to bury the stubbles and weeds quite effectively into the soil. Bunch planting 6 to 9 seedlings distanced at 9 inches to one foot apart is a common practice for the second crop also. The optimum spacing for the second crop may be 6 inches apart either way with two seedlings per hole.

Manures and Manuring.

For the Kar or the first crop, the fields receive befor
plantation 20 to 25 cart loads of village cattle manure t
or sheep penning is done i.e., about 1200 to 1500 sheep
and for the pishanam or second crop invariably no manu
plied. But of course, a few well-to-do ryots manure
nam crop also with one or two cart loads of green ma
Kolingi or Avarai.

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The analysis of the soil samples of the Rice Research Station which may in a way represent the mechanical and chemical composition of the upper regions of the tract reveals that though the soils contain fair amount of available nitrogen and phosphorus, they are low in humus content and so attention to the copious addition of organic matter to the soil seems to be the main consideration in the improvement of the paddy fields of the tract. The manurial problem of this tract is no doubt as acute as in any other paddy growing areas of this Presidency. What little cattle manure is available is hardly sufficient for manuring the nursery and Kar fields and so the only avenue opened to the paddy farmer is to explore the ways and means of raising the right kind of green manure '*in situ*' and so various kinds of green manures, to wit, kolingi, Sun-hemp pilli Persara, daincha, cow-pea, and indigo etc., were being tried at the Rice Research Station, Ambasamudram and the results of the past seasons seem to indicate that the growing of the green manure daincha soon after the harvest of pishanam in March is very successful and on an average an acre yields 10 to 15 thousand pounds of green stuff which would be quite sufficient to manure 3 acres.

Rice Research Station, Ambasamudram.

The Rice Research Station, Ambasamudram was opened in 1937 in pursuance of the policy to provide facilities for the improvement of the paddy crop in each of the most important paddy sub-tracts, as it is not the case, as a rule, that the good performance of a strain evolved under certain climatic conditions should be equally so over a wide range of land with different agronomical and seasonal conditions and as such the selection work for a particular tract should be done in that tract only. The fundamental object of the station is the improvement of the local paddy crop by the evolution of pure strains on the basis of yield duration etc. by means of pure line selection and hybridization and also to tackle the manurial and cultural problems pertaining to this tract. For the present, at this station, pure line selections have been made in the major varieties of kar and pishanam and the promising strains are under various stages of comparative yield trials at the [illegible] and it is gratifying to note that there are some good high ed fror strains in each variety and the best strains after thorough further ill be released for general distribution to the ryots after fields a so. This apart, inter-varietal trials with kar and pisha- plough tion varieties and strains obtained from other parts of get ha ct are conducted to observe whether any exotic variety lot of be the local ones with better results.

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Industries and Occupations of Tinnevelly District

BY

D. SANKARANARAYANAN, DIP. GEOG.

The census of 1931 shows that 47·1% of the population in the Thambaraparni Basin do really no work of any kind being either too old or too young or dependant on others for their sustenance, and that the actual workers, their working dependants and those of them who have more than one occupation form 62·9%. The corresponding figures for the Presidency are 44·5 and 63·5. A large body of non-working dependents may be due to the actual workers being employed outside the area in Ceylon or in the Straits and supporting their relations by money remittances. The percentage of people actually depending on agriculture is 25·8.

The ordinary artisans, the carpenters, the goldsmiths, the blacksmiths and the potters exist in most village communities and their work is much the same as elsewhere.

In a recent year there were 102,109 acres in the Basin under cotton cultivation. Of this area 96% is under indigenous cottons mainly Karunganni and Uppam. Pullyichi or Mailam was cultivated as mixtures in varying proportions. Only 4% of the cultivated area was under Cambodia cotton and half of this grown under irrigation and the rest treated as rain-fed crop. There are two large spinning mills one at Papanasam and the other at Tuticorin. Hand looms for the production of cloth exist throughout the area. A few spinning wheels are still at work as a result of Khader propaganda but the activity is not so progressive as in 1920-21. The Tinnevelly mills in Vikramasingapuram village in Ambasamudram taluk which are driven by water power represent a very great advance on the idea first put forward by Lord Napier in 1869. Mr. F. Harvey engaged in the cotton trade of the District proposed in 1883 to build a mill at the foot of the hills of Papanasam by diverting the Tambaraparni river water above Papanasam falls to get the immense power developed by the water in its descent from the crescent of the hills to the plains. In 1885 his scheme bore fruit and the mill was started with 10 000 spindles. A second and much larger mill was started in 1908 and in 1930 after the amalgamation of the Tinnevelly and Madura mills a further extension was carried out and now 1,700 employees work on 60,000 spindles. The supply of water from the rivers thus works two sets of turbines which develop between them 1,350 H.P. and after use the water returns to the river below the Kodamelagian dam. Further extensions took place in the middle of 1930 and a mill to accommodate 100,000 spindles was opened and now 25,000 spindles are working in it. The building is one of the most modern fire proof construction and this new mill will eventually provide employment for 3,000 workers. These 85,000 spindles consume 4,600 tons of cleaned cotton annually from Tinnevelly, Madura, Ramnad and Coimbatore districts and their annual output of yarn is 4,200 tons in counts from 2s to 44s.

The Coral Mills of Tuticorin was started in 1888 and is under the management of Messrs. A. & F. Harvey. Now there are 73,560 spindles engaging 2,000 labourers. The consumption is 3,800 tons of cotton annually and the out-turn is 3,400 tons of yarn.

The hand gin was in vogue for a long period and it is said that this forms one of the wedding presents to the bride-groom among the Kammavar community. It is called a Pirai and a good number of them still exist in the black soil country. The Steam ginning factory was introduced in 1894 and now small ginneries from 2 to 8 or 10 gins are to be found in villages all over the cotton growing area. Cleaned cotton had to be pressed to reduce the bulk and now there are 7 power-driven presses in Tuticorin of which 6 belong to European firms. The growth of the mill industry in India and the consequent large consumption of cotton has reduced the supplies available for export with the result, that some of the presses are doing very little work.

The weaving of cotton is a hereditary employment of the Kakkalayans, Pattasalayans and Pattunulkarans and forms the chief occupation of a large number of Muhammadans and Iluvans and a few Kolia Parayans. Their streets are characterised by width, lined with two rows of trees to give shade to the workers at the long line of out-stretched warps. The most prosperous centres of the industry are Ambasamudram, Kallidaikurichy, Viravanallur, Pottalputhur, Tenkasi and Kadayanallur. Pattunulkarans are numerous in Viravanallur, Vellangudi and Palamcottah. Muhammadam weavers are found in Kallidaikurichi, Pottalputhur, Melapalayam, Kayalpattanam and Sedunganallur. Iluvans are common in Ambasamudram and Srivaikuntam taluks. Till the import of machine-made cloth in 1860 broad cloth of the district found a ready sale in European markets. At present weaving is a profitable industry only in a few centres where the existence of a class of capitalists has rendered possible a combination of workers and a fairly large and continuous out-put of woven fabrics. The rich Brahmins of Kallidaikurichi had their brokers, or tharagans in all the villages of Ambasamudram taluk. They advance money to the local weavers for the purchase of yarn etc., and buy the finished products from them and till recently were sending them on to Malabar, Cochin and Travancore where they owned their own shops. In Kallidaikurichi alone there are more than 1,500 looms. Altogether there were 20,000 looms all using mill yarn from 20s to 60s though yarns of finer counts were used to a considerably lesser extent. Weaving of coarse cloth is done by Kakkalayans and Adidravidas. Street sizing continues and warping to a great length as 190 yards is not rare and a warping mill exists for every 10 weavers' houses. In warping for great lengths ten or fifteen weavers join together. Coarse cotton sarees 13 cubits long for lower classes are largely made and exported to the plantation coolies to Ceylon and the straits. Sankaranayanarkoil, Pulliyankudi, Kadayanallur and Viravanallur are the chief centres for the sarees and they range from 2 to 6 Rupees and an average weaver earns about Rs. 10-8-0 a month. Towels $3 \times 1\frac{1}{2}'$ cubits are in great demand locally and among the Malayalis. Melapalayam continues to be the largest centre and the annual export of cloths is to the extent of Rs. 15 lakhs. There are 4,000 Mussalman families engaged in weaving and 800 looms are fitted with fly shuttles. The products range from lungis to sarees and the chief foreign markets for these goods are Ceylon, Burma, Penang, Singapore and Travancore. Cheap varieties of lungis are in great demand among the Singhalese for under-wear. Cheap Japan yarn is now used for Lungis and an average weaver earns As. 8 a day. The Pattasalayans and Pattunulkarans of Shermadevi, Viravanallur and Kallidaikurichy produce superior kind of dhoties for men known as mundus and nariyals in which there may be borders of silk and lace. Sarees of pure silk in warp and weft are woven by about 50 Pattunulkarans' families especially in Viravanallur. For less costly sarees cotton is used in the weft. They get their silk dyed ready from Kumbakonam and there is a clean profit of Rs. 8 for each silk saree. The Pattasalayans have taken to this work also. At Vadakankulam the mission authorities are trying silkworm rearing.

Carpet weaving on a large scale goes on in Palamcottah, Melapalayam, Munnirpallam, Pettai, Alwarthirunagari and Srivaikuntam. The weavers are mostly Muhammadans. There are two sizes of carpets 7½ ft. by 3 ft. and 15 ft. by 6 ft. Mill yarn is used and the carpets find local sales mostly. The district jail of Palamcottah manufactures office tapes of various widths supplied for the Government departments and the broader variety for cots and curtains. Gold and silver laces are manufactured by a few Muhammadans in Viravanallur. In several mission institutions the boarders and girl students are taught lace making and embroidery. Pillow lace made in Tuticorin, Vadakankulam and Idayankudi was in great demand in Europe before the war.

Dyed yarn from Madura has almost killed the dyeing industry. A few Pattasalayans in Ambasamudram taluk, some Sayakkarans in Siniyapuram, Tenkasi, Vallanadu and in one or two places and some Mahammadans in Melapalayam and Kayathar still carry on dyeing mostly in blue and red. Blue dyes are obtained from the Indigo plants.

Palmyra mats are common in places where the Palmyra tree is plentiful and the women folk of the tappers' families during the off season employ themselves in making mats and baskets and other useful articles. Large number of mats are bought at Kulasekarapatnam at 100 per Rupee by the merchants and shipped to Tuticorin or Bombay where they are used in the local bazaars to sit on or sold to steam-ship compaines. Mats of a coarser texture are manufactured by Muhammadan women in Srivaikuntam and Trichendur taluks and sent to Pettai and Tuticorin for local consumption mostly or for packing goods for transport. Smaller coarse mats are in much demand at Calicut for packing fish. Nadar women also take to the weaving of Palmyra mats and earn about annas two per day.

Mats of korai grass are woven mostly by Muhammadans at Pattamadai, Alwarkurichi, Kayathar, Kalakad and Viravanallur from the korai obtained from the beds of tanks and channels the right to gather it being sold by public auction by Government. A variety of colours is given to it and woven by hand to a warp which is made of aloe fibre. Pettai and Harikesavanallur are the collecting centres for exports. Marriage mats are usually made with red coloured strands of the grass and at least a pair of mats are given for the bridal party. Madras market gets a great proportion from Tinnevelly District. Very superior mats are woven in five or six Muhammadan families at Pattamadai who have traditionally taken to it. So fine are the mats that even if they are crumpled in the hands they are not damaged and such mats 6 ft. by 3 ft. costs each from Rs. 10 to 35. The korai for the special Pattamadai mats are grown on the banks and bed of the Thambaraparni for 5 miles with Karungadu as the centre. The Pettai Muhammadans are the lessees. The korai grass has to undergo several processes for the superior mats and the superiority is judged from the number of threads in the warp for a span which ranges from 16 to 120; 42 kans is considered to be the marking between the superior and the ordinary.

The Palmyra provides a variety of occupations for a large number of the people in the Basin. Loose red soil with sub-soil springs provide the best edaphic features for the Palmyra. It is not possible to enumerate the 801 uses idyelized by a Sanskrit poem, to which the tree can be put, for want of space. The rain falling in March and April is important to the Palmyra for the development of the spathe. For purposes of tapping the spathe is pruned twice a day and the daily yield of a normal male tree is half to one Madras measure. To avoid fermenting the pots are lined with lime and the juice then is sweet. It is called pathani which forms a delicious drink in the hot seasons. When the juice ferments it becomes Kallu. The quantity and duration of yield are in the case of all kinds of palmyra most uncertain. Most of the juice is utilised in the preparation of palmyra jaggery known as karupatti. This is mostly collected at Tinnevelly junction and the annual export is 11,000 tons. Of late there is much home consumption and the sugar factories at Thachanallur, Kulasekarapatnam and Alwarthirunagari purchase large quantities. The price has risen to Rs. 20 per candy of 500 lbs. from Rs. 15. Tapping is the monopoly of the Nadar caste but of late the tea and rubber estates of Ceylon, Travancore and Malaya, sheep-keeping and garden cultivation at home have attracted many; the spread of education especially through the agency of Christian missions has opened a new field of activity for many Nadars. Enormous tracts of trees in Tenkasi, Ambasamudram, Nanguneri and Trichendur areas grow untapped. The Nadars from Nanjankad in Travancore migrate in April after tapping in their country to Nanguneri, Trichendur and Srivaikuntam and tap the trees according to terms settled with the owners. The tappers' work is very severe in the season when he climbs about [illegible]0 trees twice daily. The popular farm of the lease is varam, but fixed rental system is not also uncommon. The Lakshmi Sugar Mills at Alwarthirunagari started in 1890 and the Pettai sugar mills at Tinnevelly founded in 1895 are carrying on work under

Nattukottai Chetty management. The East Indian Distilleries started work in Kulasekarapatnam in 1912 but in 1925 the factory had to stop work for want of adequate supply of jaggery and sweet juice both to Kulasekarapatnam and Nellikuppam factories.

Gingelly oil is the chief oil produced in the area by the Vanniyar community and Pettai is a good collecting centre. It is used for bathing and edible purposes. Kerosene oil is now common in towns and even in villages. Castor oil for lighting and medicinal purposes is used. Oil from the seeds Illupai and Pinnai is used for lighting lamps but it becomes solidified in the cold season. Margosa oil is used for children for convulsions. Coconut oil is generally imported from Malabar and Colombo. Tomco oil is at present largely used for caking purposes and the Tata Oil Company supplying the Tomco Oil is located at Cochin. Bell metal ware are made in a number of places the chief centres being Vagaikulam, Mannarkoil, Seythinganallur, Eral, Tinnevelly, Narasinganallur and Sankaranaynarkoil. The liquid metal an alloy of lead and copper in a certain proportion when poured into the moulds hardens in twelve hours. Vatils and eating plates are greatly in demand in Ceylon. Tumblers and Sombus are a speciality of Sankaranaynarkoil while Kujas, cups and vessels with broad mouth are a speciality in Seythinganallur. There are about 100 ho[illegible] in each village doing bell-metal work. Brass plates are imp[illegible] and Kannasaris work on them usually with bell-metal wor[illegible] Hindu idols are made at Vakaikulam, kudams or water pots made at Sankarankoil and Pettai and other places are noted broad mouthed vessels as koparais.

The Avaram bark is used for tanning purposes and good leather exported to Europe is produced in a tannery near Pudukottai, other factories meet the local demand and the ordinary Tinnevelly slippers are noted for their strength and neatness.

Beedi manufacture of late is an important industry. Every village with a fair Muhammadan population has a small factory where beedies are made. In Mela Palayam 5,000 Muhammadan families are engaged in this work. Mukudal has risen in recent years where Sokkalal Beedies are patented.

Fishing is the occu[illegible] [illegible]ettai and Harikar[illegible] coast villages and [illegible] [occ]upation of hundreds of Paravars in the sea-be half a lakh [illegible] [im]por[t]. The total catch at Tuticorin has been estimated to Alanthal[illegible] [illegible]str[illegible] of Rupees per annum. From Tuticorin, Manappad and lages in th[illegible] large quantities of salted dried fish are sent to the vil-commo[illegible] the interior and even shipped to Ceylon. The valai is the [illegible]hest kind; others are sardines, the seer, the sea bream and

the red mullet. The pearl fishery industry in 1925 lasted from 17th February to 27th March with a catch of 1,648,312 oysters which brought a net revenue of Rs. 26,802 to Government. Another fishery was held in 1927 when 103·6 lakhs of oysters were fished and the net revenue was Rs. 157,383. The chank fishery of the Gulf of Mannar is another large item. The shells are scattered about and the divers have to move from place to place. A diver earns about Rs. 1-8-0 to Rs. 6 per day and in 1929 to 1930, 612,680 chanks were collected getting a revenue of Rs. 246,651 to the State. They are mostly exported to Calcutta and heavy demand comes for the chank bracelet from the women of Tibet.

Trade Centres of Tinnevelly District

By

Dr. V. Krishnan, M.A., Ph.D., Dip. Geog.

Stuart writing about the Tinnevelly District observes that it is an 'epitome of the Madras Presidency.' Almost all the economic activities of the Presidency are carried on in the District to a smaller or bigger scale depending on the circumstances favourable or otherwise to the growth or decay of such activities. The factors that have contributed to the growth and development of various trades in the different centres in the district are of a permanent and natural character. Artificial stimulus like the patronage of courts to particular kinds of trades in particular centres has not done much to create trade relationship between one centre in the District with another in the same District or outside the District.

The differences in the peoples themselves, the differences in the stage of industrial and agricultural development, the differences in the resources of respective lands are the main factors that have brought the existence of some of the main centres of trade in the District. For example, Ambasamudram and Tinnevelly situated in the clayey basin of the Tambraparni Basin are important export centres of paddy and other raw products of the forests nearby like timber to the far remote drier regions of Nanguneri and Koilpatti Taluqs. Tisianvillai in the Nanguneri Taluk is the place where the exchange of products grown in drier regions round about takes place for those raised in the river valleys of the Tambraparni.

The configuration of the country, the differences in soil fertility, the adequacy of roads and railways and convergence of the same in particular places have given rise to another set of trade centres. Koilpatti in the centre of the black-cotton tract and Tenkasi, Alangulam, Sankarankoil in the red soil tract are centres which export cotton and chillies and other garden crops in exchange mainly for food crops of cheaper variety from the clayey region of the Tambraparni valley.

The products of the well used mountains and those of the well developed plains must for ever be different. The full utilization of mountains therefore means minerals, cutting wood, collection of

minor and major products and conserving the same, fruit culture, mining and quarrying industries. The mountain people want the products of the plains which can be only paid for with those raised in mountains. Such is the trade that now passes between the 'teri country' in the Trichendur Taluq and the adjoining taluks of Trichendur. The chief exports of Elangudi, Naduvakurichy and Kuthiraimoli theri are palmyra jaggery, leaves, fibre, and baskets and they import mainly consumption staples like paddy and other manufactured cotton fabrics.

The District has also got a maritime sea-board. The shoreland of the Srivaikuntam, Trichendur and Nanguneri Taluqs have got an enduring trade with the interior regions of Tenkasi, Ambasamudram, Tinnevelly and Sankarankoil Taluqs in fish, cereals salt, chanks and palmyra products. Kayalpatnam, Trichendur and Tuticorin are some of the important ports through which products of the well developed interior region in and outside the district pass.

The trade centres of the district may be divided into those which play an important part in the international commerce, those which play a chief part in the distribution of products from this district to other districts and those which act as centres for the distribution of products between one region and another or between one portion of the Taluq and another portion. To this class belong the numerous shandies in the district which are held in more than 80 villages.

Tuticorin, Kulasekarapatnam and *Kayalpatnam* are the three important sea port towns of which Tuticorin with its harbour is the most important, possessing a rich hinterland producing different types and varieties of crops. In the earlier days compared with Kayalpatnam and Kulasekarapatnam this port was of no importance at all. During the American civil war it suddenly shot up to prominence consequent on the large export of cotton through this port on account of the phenomenal rise that took place in the case of Indian cotton. Since then its progress has been very rapid and so much so Kayalpatnam and Kulasekarapatnam are nowhere when compared with the commerce of this port. Yet some native crafts ply between Tuticorin, Kulasekarapatnam and Kayalpatnam, where the products of the palmyra the chief crop of the hinterland such as jaggery, molasses, jaggery mats baskets and fibre are assembled by the local paravans for export to Tuticorin. Onions, a local crop of importance is exported from this place to Colombo on a large scale. Manufactured articles mainly of cotton brought from Panagudi, Melapalayam, Munnirpallam and other weaving centres nearby are also exported to Colombo. The main industry of Tuticorin is that connected with the treatment of Raw cotton. Besides cotton spinning, senna pressing was prominent in those days. The local chank industry is also likewise only of historical interest. The salt produced in and round this port is exported through this port.

Ambasamudram, Koilpatti, Sankarankoil and *Kallidaikurichy* are some of the more important centres connected with the treatment of cotton mainly and trades in other products raised in and around those places.

Ambasamudram, situated on the Northern bank of the Tambaraparni river shortly after its emergence from the ghats is a bridge-town as well as a foot-hill town. Being situated on the great western main road between Tinnevelly and Travancore, at a place where the perennial Tambraparni is crossed by a bridge, at the meeting-place of the plains and the hills of the Western Ghats, it is a very good pooling centre for the agricultural specialities grown in Kadayam, Pavurchattram, and Alangulam and palmyra products of the red soil region of the southern portion of the Tenkasi Taluq. Thousands of bales of cotton yarn are exported from Ambasamudram, the product of the Harvey Mills at Papanasam. Unlike Koilpatti wherefrom also cotton yarn and lint are exported, Ambasamudram is not situated in the heart of the cotton-growing tract. The only factor that has contributed to the growth of the industry in this place is the availability of cheap motive power in the head-waters of the Tambraparni before it reaches the plains, which was utilized for the turning of the turbine. The availability of cheap labour was an auxiliary factor. The three mills have about 40000 spindles. The Cambodia Cotton of Sankarankoil area, and Tinnevelly of the Koilpatti region and cotton even from beyond Satur and Virudunagar occasionally, are brought to Vikramasingapuram direct, four miles to the west of Ambasamudram, at the foot of the Western Ghats on the northern bank of the river Tambraparni, on the road which girdles the Western Ghats connecting Tenkasi, Sankarankoil and Srivilliputtur with Ambasamudram. On account of these factors Vikramasingapuram has become an assemblage centre for raw cotton. The importance of Vikramasingapuram is further increased by the first bridge across the Tambraparni being situated to the south of the village. The completion of the hydro-electric project which

is in progress now will make it still more important. It is likely that in the near future with the help of cheap hydro-electric power available locally, with excellent climate, abundant supply of cheap and trained labour force, coupled with the enterprise of the big financiers of the village just on the other bank of the river, it may become another 'Manchester.'

Hand-woven cloth is exported from Ambasamudram and Kallidaikurichy by rail and road to the Travancore State and other parts of the District. Once the entire trade in cloth of the District with Travancore was in the hands of the Brahmins of Kallidaikurichy whose vast riches (which have gone down now) are attributable only to this. Enterprising as they are by nature the Brahmins of Kallidaikurichy have specialized in a system of Banking comparable to that of the Chettiars of Ramnad District and were financing the whole of the cottage industry of the region nearby. Ambasamudram towels in this Presidency and Ambasamudram and Kallidaikurichy 'Muris' and 'Mundoos' in the Travancore State are some of the familiar trade names; and these articles command a good market even to-day.

Vagaikulam in the vicinity of Ambasamudram is an important centre in bell-metal industry. Some of the biggest and finest Bells and Idols in the well known temples in the Presidency are made here by the local 'Kannans'.

Tinnevelly.—All roads lead to Rome, so also all roads in the District lead to Tinnevelly. The convergence of all roads at this place has made it an important nodal town. Its importance is further increased by its being situated right in the centre of the District. With its satellite town of Pettai it controls the entire internal trade of the District. Grocery trade is mainly concentrated in Tinnevelly and the trade in oils, oil-seeds, and fancy goods is concentrated in Pettai which directly imports the latter from Bombay and Madras.

The bulk of the inter-taluq exchange of products is done through weekly shandies held in some 80 villages in the District. These shandies are temporary centres of intense trade activity on specified days. This institution called 'Shandies' has greatly influenced the human geography of the region by giving rise to a particular class of traders whose main economic activity is to carry products from one shandy to another. A sort of seasonal [illegible] is brought about in the lives of the people of the district [illegible]se shandies. For example, a market trader and a [illegible]dy bandy-walla have come to mean a certain occupational group of people as distinguished from others. A market trader may start from Ambasamudram with paddy to Tisianvillai, about four days journey by road, and sell it there and return with vegetables, visiting the various shandies on the way at Kalakkad, Panagudi, Mela Kallur, Pattamadai and Sermadevi, Kallidaikurichy, etc. The shandy trader does not follow a particular course or route. Like a tramp vessel he visits places wherein he could get business. Thus the shandy or market trader may return to his place within a week or fortnight, the length of the period depending on the condition of the market on his way. These shandies have further given rise to particular subsidiary occupations like shandy money-lending, shandy broker etc.

Certain centres of pilgrimage and famous shrines become seasonal trade centres where big fairs are held in connection with the festival of some local deity to worship whom huge congregations of people come from far and near. Cattle fairs are held only on such occasions. The fairs last for over a month though the festival proper is for shorter duration, say, ten days. New heads of cattle for agricultural operations in the District are supplied only by these fairs. Exchange of used cattle for new ones and out-right purchase of new cattle to the value of thousands of rupees, is done in each of these places like Kalugumalai (Thai Poosam and Panguni Uttram festivals), Sivalapperi (cattle fair, Navarathri fair) Alwarthirunagari (cattle fair etc.) Sankaran Koil (Audi Tapasu and fair).

Population of Tinnevelly District

By

M. P. Rajagopal, B.A., L.T., Dip. Geog.

Introduction

This district which is the most southerly in the Presidency is bounded on the north by Ramnad, on the east and south by the sea, and on the west by Travancore. Under Sir William Meyer's redistribution scheme the taluks of Srivilliputhur and Sattur (excepting 21 villages of the latter) in the old Sattur division of the District was transfered to the newly constituted Ramnad District. In G. O. No. 1127 Press, dated 18th, June 1927, the taluks of Anjengo and Tangasseri were detached from Malabar District, and included in Tinnevelly District with effect from 1st. July, 1921. So the District is now made up of the nine taluks of Ambasamudram, Kovilpatti, Nanguneri, Sankaranayinarkoil, Srivaikuntam; Tenkasi, Tinnevelly, Tiruchendur; and Anjengo and Tangasseri. The addition and the revision of the frontier so far has brought down the area of the District to 4, 315 sq. miles.

Population

According to the census of 1931, the District had a total population of 2,046,907. Tinnevelly District comes tenth in the order of population among the districts of Madras and is above Madras average (1,797,696). There are no less than 19 towns of over 10,000 inhabitants and numerous villages of over 5,000. The following Table classifies the population in towns and villages:—

Total No. of inhabited towns and villages	Population	Under 500		500–1000		1000–2000		2000–5000	
		No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.
999	2,046,907	180	46,589	199	149,947	317	446,330	244	712,795

5000–10,000		10000–20000		20000–50000		50000–100000		100000 & above
No.	Pop.	No.	Pop.	No.	Pop.	No.	Pop.	
40	272,194	13	176,371	3	72,330	3	168,508	Nil

The largest towns in the order of population are Tuticorin, (59945) Tinnevelly (56591), and Palamcotta (51972). Tuticorin is one of the largest ports in the Presidency. Tinnevelly, at least from the times of the Nayakkan rulers, forms the headquarters of the district to which it gives its name. Palamcotta with its fort, three miles from the town of Tinnevelly on the opposite side of the river Tambraparni assumes importance as a strategical position, and from the early days of the Company's interference in the District became the military headquarters.

Graph on p. 287 shows the growth of some towns in the District from 1891-1931. In the District there are many towns which have increased little or have actually declined during the decade as compared with the pronounced growth of Tuticorin, Tinnevelly, Palamcotta or Tenkasi. Sermadevi, Alwar Tirunagari and Srivaikuntam are instances. The number of people living in Towns in the District is very high being 25%.

Density of Population

The District stands ninth among the districts in the Presidency (Madras excepted) in regard to the density of its population, with an average of 474 persons to the sq. mile. The density is above Presidency average 329. The distribution of population in the District is as shown below :—

Taluk	Area (in sq. miles)	Occupied houses.	Males.	Females.	Total Pop. (in 1931)	Density per sq. mile
Ambasamudram ..	490	50,428	96,059	106,451	202,510	413
Nanguneri ..	693	9,303	119,267	135,282	254,549	367
Kovilpatti ..	1085	76,963	174,807	182,110	356,917	329
Sankaranayinarkovil ..	634	59,230	132,888	135,192	268,080	423
Tenkasi ..	403	56,432	123,526	125,943	249,469	609
Tinnevelly ..	326	56,020	113,042	124,163	237,205	728
Tiruchendur ..	323	57,286	111,068	126,103	237,171	734
Srivaikuntam ..	361	57,640	113,311	120,929	234,240	649
Anjengo & Tangasseri .	1	1,140	3,191	3,575	6,766	6766
District Total ..	4,315	474,442	987,159	1,059,748	2,046,907	474

Diagram 1 also shows the distribution of population in the taluks in the descending order of strength.

A glance at the Population Map clearly shows that the taluk with the largest area—Kovilpatti—is the most thinly populated, and Tiruchendur the most densely inhabited. Diagram 2 clearly shows that the density is below District average (474) in Kovilpatti, Nanguneri, Ambasamudram and Sankaranayinarkoil. The riverside taluks are all above the District average and come in the following order—Tiruchendur (734), Tinnevelly (728), Srivaikuntam (649), and Tenkasi (619). Ambasamudram's figure of 413 would be much higher if forested areas were left out of account from the total area. The lowest densities come from extreme North-east and South-west, i.e. Kovilpatti and Nanguneri respectively. These are dry areas with uncertain rainfall.

Variation in Population

Owing to the fact that the district was reconstituted in 1910, it is impossible to gauge correctly the increase of its population over any considerable period. The following table compares the population as ascertained at the census of 1931 with those of the previous census. (Previous census figures have been adjusted to allow for inter-district transfers, i.e. to show the population existing at these enumerations in the areas now forming the District. On account of changes in 1901-1911 in the District constitution, it is not possible to make such adjustments for census earlier than 1891).

1931	1921	1911	1901	1891
2,046907	1,907,314	1,796,191	1,663,312	1,535,442

1921-31	1911-21	1901-11	1891-01
139593	111123	132879	127870

Net variation in the period 1891-1931 :—511,465

Males

1931	1921	1911	1901	1891
987159	929,338	868323	806424	746571

Females

1931	1921	1911	1901	1891
1059748	977976	927868	856888	788871

A reference to the census figures relating to the old district of Tinnevelly shows that, in spite of the great famine of 1876-1878, the population increased slightly by 0·3% in the decade 1871-1881. In the next ten years the rebound usual after scarcity took place, the advance being as much as 12·7%. In the period 1891-1901 the growth of the population was 8·3% or slightly greater than the Presidency average. In the decade 1901-1911 the increase was 8%, a figure slightly below the Presidency average. In the intercensal period 1911-1921 the population increased by 6·2% and in the next ten years the increase was slightly higher 7·3%.

Graph on p. 287 shows the variation in population from 1891-1931. The subjoined statement in the following table shows variations in the taluk figures:—

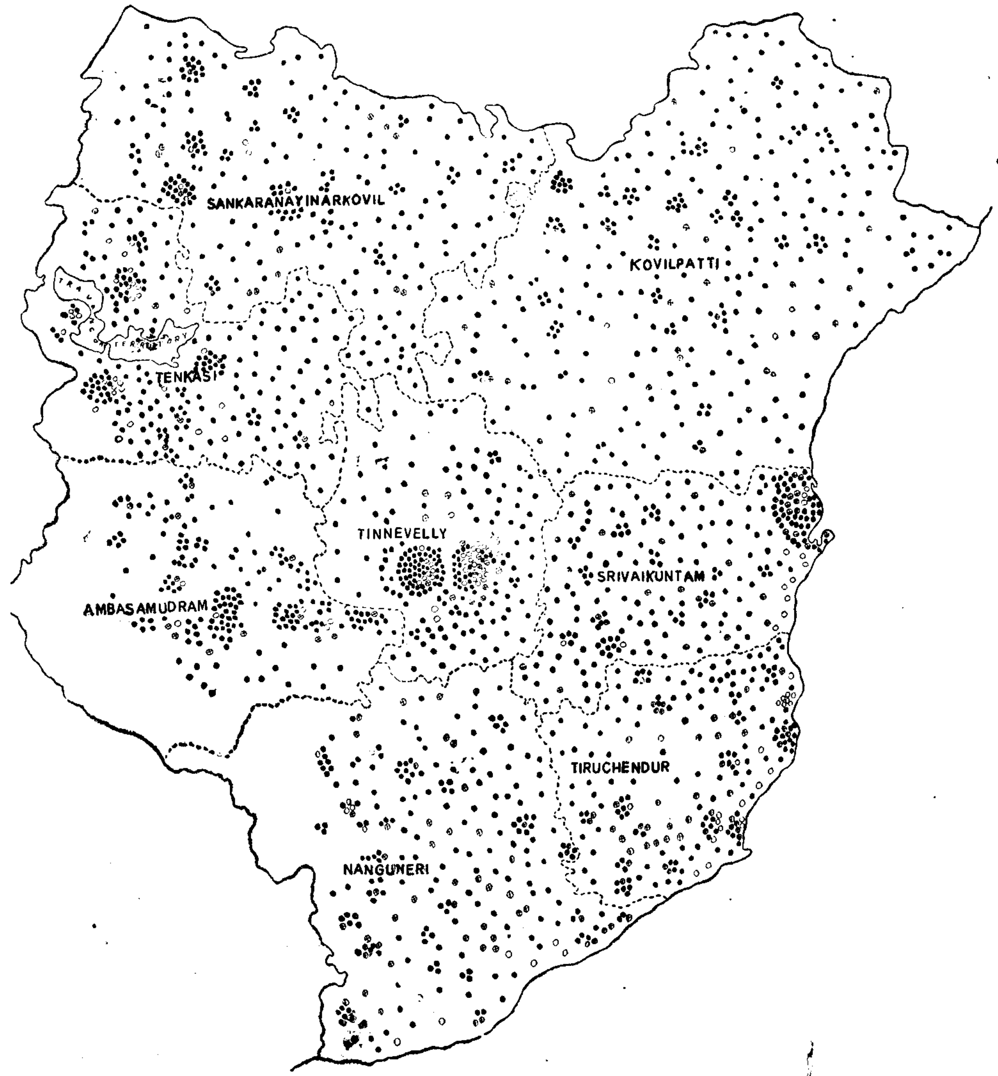
Taluk		Loss or gain of pop. percent between				
		1891-01.	1901-'11.	1911-'21.	1921-'31.	1901-'31.
Ambasamudram	..	−0·6	+6·0	+0·1	+3·7	+10·9
Kovilpatti	..	+4·6	+3·9	+3·2	+2·5	+10·1
Nanguneri	..	+16·1	+3·6	+12·2	+8·2	+25·7
Sankaranayinarkovil	..	+10·2	+9·7	+10·0	+6·7	+28·5
Srivaikuntam	..	+7·1	+21·9	+6·5	+8·9	+41·4
Tenkasi	..	+12·6	+11·8	+14·1	+12·1	+43·0
Tinnevelly	..	+5·4	+8·7	+4·5	+7·3	+27·8
Tiruchendur	..	+14·7	+3·6	−0·3	+11·3	+15·1
District	..	+8·3	+8·0	+6·2	+7·6	+25·3.

The Tiruchendur Taluk shows a decrease in 1921 of over 0·3% over the figures of 1911 (which had been inflated owing to the occurrence of the Masi festival held at the time of taking census). The census of 1931 recorded an increase of 11·3% over the population in 1921. While all the taluks returned during the 20 years (1911-1931) an increase in population,—the district increase being 13·5%, the advance was most marked in Tenkasi 26·2%, Nanguneri 20·4%, Sankaranayinarkovil 16·7% and Srivaikuntam 15·4%. Tiruchendur taluk returned an excess of 11%, Tinnevelly 11·8%, Kovilpatti 5·7% and Ambasamudram 3·8% only. The gain of population per cent between 1901-1931 is highest in Tenkasi 43·0%. The reason is due to the rich irrigation at the foot of the hills in that taluk and its industrious Nadar population who have taken largely in these parts to well cultivation. Srivaikuntam ranks next 41·4%

TINNEVELLY DISTRICT MAP

Showing Population.

One dot=1,000 persons.



Solid dots represent Hindus, hollow dots, Muslims, and hollow dots with cross inside, Christians.

due to the growing prosperity of the port of Tuticorin and partly to the extension of wet cultivation under the Srivaikuntam irrigation system.

The Growth of Population in the District *

There are two factors governing the growth of population in any country, namely, 'Natural increase' and 'Migration.' By the term 'natural increase' is meant the excess of births over deaths while the term 'migration' comprises the difference of immigration over emigration.

In Tinnevelly District during the last decade, from 1923 onwards the birth-rate exceeded that of the Presidency. The following table shows that throughout the period there had been excess of births over deaths :—

Ratio per 1,000 *population of*

Births.

1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
30.6	32.1	34.7	36.3	35.9	38.6	37.7	40.9	38.5	39.9	37.1

Deaths.

1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
18.8	20.6	21.9	27.1	27.6	27.5	24.4	28.1	31.2	26.3	24.2

Presidency average.

Births.	Deaths.
34·6	23·9

The death-rate in the district is not high as the general health of the district as a whole is good. The following table shows the causes of deaths in the District :—

Ratio of deaths per 1,000 *of population*

District average for:—

Cholera	.. 1·60	Dysentery & Diarrhoea	.. 2·28
Small-pox	.. 0·15	All other causes	.. 18·41
Plague	.. Nil		
Fever	.. 5·08	Total	.. 27·52

*The population problem in India—P. K. Wattal (p. 11).

Fever accounts for about one in six of the total number of deaths in the District, and mortality from Cholera is not much as it was before. The District is free from plague.

As in other districts in the Madras Presidency, we find in this District a greater percentage of female population than male population. Graph 3 shows the growth of Male and Female population respectively. Emigration during the decade was affected to some extent by the passing of the Emigration Act of 1922, which brought under control all assisted emigration to Ceylon and Malaya. Though no reliable figures are availabe there is reason to believe that there has been a rapid decrease, in the decade 1921-1931, in the total number of emigrants from the District.

Hence the 'Natural increase' and the decrease in 'Migration' during the last decade, together account for the rapid growth of the population in the District.

Mother Tongue.

The principal language of the District is Tamil which is the parent tongue of about 89·8% of the total population. Telugu is the language of about 8·6%; for a smaller section, Canarese, Hindustani and Malayalam are the languages; while Saurashtri, Marathi and other non-Presidency languages are spoken by still smaller section. Diagram 3 shows the distribution of population per language in the District. Tamil is spoken wholly in Ambasamudram, Nanguneri, Tinnevelly and Tiruchendur; and Telugu is spoken by a large number in Kovilpatti and Sankaranayinarkovil taluk, and by a smaller number in Srivaikuntam and Tenkasi taluks. The Nayudu and Reddi communities constitute the bulk of the Telugu-speaking section. Telugu Brahmins are sprinkled over the District in small groups.

Religion

In the District about 83% of the total population are Hindus, 5·9% are Muslims and 11·1% are Christians. Diagram 4 shows the percentage of Hindus, Muslims and Christians to the total population in the District as a whole, and in each taluk in particular. The proportion of Christians to the total population is higher than in any other district in the Presidency. The following table gives the rate of increase of the different communities in the District :—

DIAGRAM I

COMPARISON OF THE POPULATION OF THE TALUKS OF THE TINNEVELLY DISTRICT ACCORDING TO THE CENSUS OF 1931

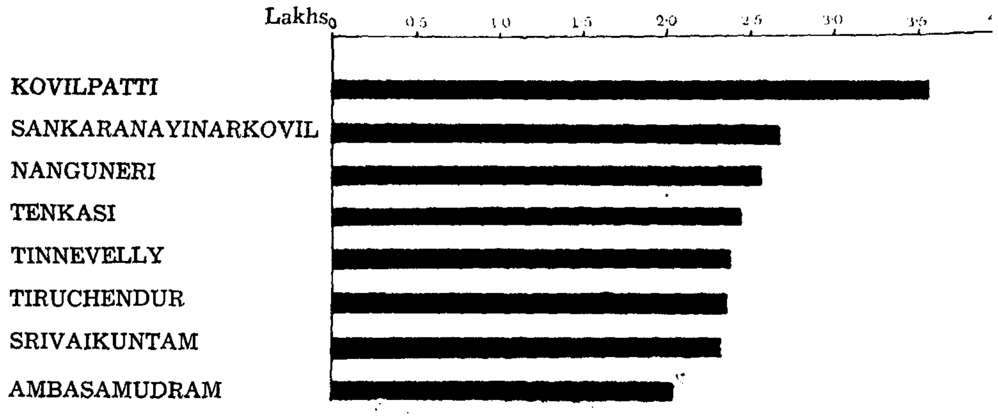
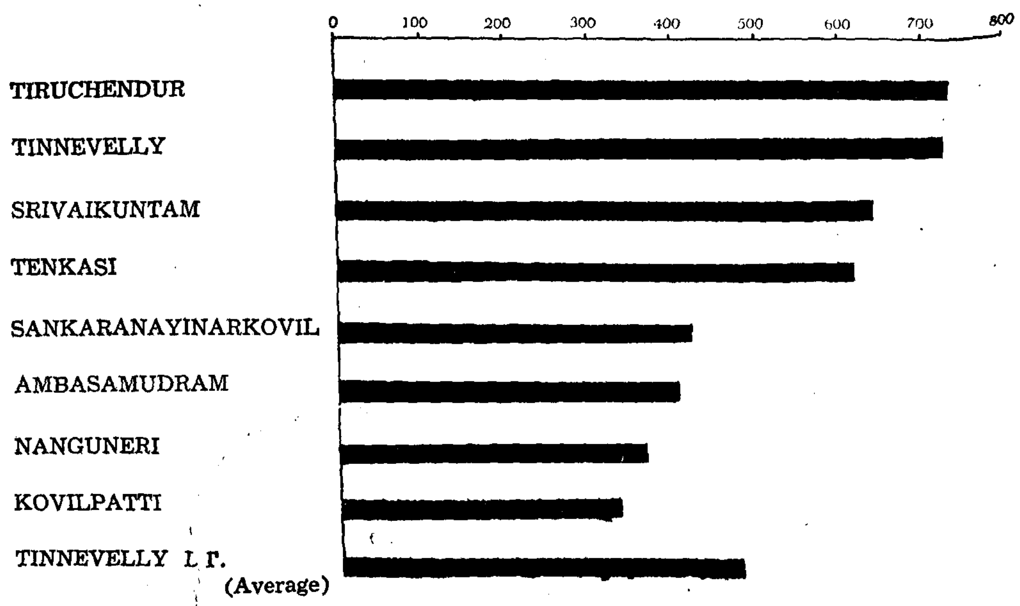


DIAGRAM II

COMPARISON OF THE DENSITY OF POPULATION PER SQUARE MILE OF THE TALUKS OF THE TINNEVELLY DISTRICT



Percentages of rate of increase

	in 1891–1901.	in 1901–1911.	in 1911–1921.	in 1921–1931
Among Hindus ..	+7·4	+6·2	+6·0	+6·2
Among Muslims ..	+6·1	+10·4	+3·4	+10·3
Among Christians ..	+9·7	+16·7	+9·3	+18·3
District. ..	+8·3	+8·0	+6·2	+7·3

Christians.—In the decade 1921-1931, the Christians (almost entirely Indians) increased by 18%. In the Tiruchendur Taluk which contains several villages wholly inhabited by Paravars (fishermen mostly converted to Roman Catholicism), the Christians comprise nearly a fourth of the total population (25·3%). Nanguneri (19·2%) and Srivaikuntam (14·5%) come next. The Christians have gained ground markedly during the last four decades, evidently by conversions. The Protestant Missions have been successful chiefly among the Nadars and the Roman Catholic Missions among the Paravar fishermen.

Muslims.—Muslims who constitute only 5·9% of the population of the District are concentrated in the three taluks of Tinnevelly (12%), Tiruchendur (9%) and Tenkasi (9%). They belong to a class usually known as 'Labbai.' The Muslim population is distributed more along the coast than in the interior, as Muslims are a sea-faring people.

Hindus.—The Hindus constitute the bulk of the population. The Brahmins form only 2·6% of the total population.

The principal castes other than Brahmins are:—the Nadars found along the sand-dunes, and known as the palmyra-climbing and toddy-drawing castes and who are mostly converts into Christianity; the Maravars; the Vellalans who come next to Brahmins in the social scale; the Vadugars and Kammans (commonly known as Naidus) and Reddis concentrated in the Black C[illegible] lands; and the Iluvans who are mostly weavers.

Literacy.

Judged by the census returns, Tinnevelly District stands fourth among the Districts of the Presidency, in regard to the literacy of the population as a whole. The census of 1931 discloses a great advance in education in the District. 25·7% among males were returned as literates, or an increase of 12·2% in 20 years. Literacy among women is marked—4·7%, an increase of 80% over the figures for 1911. The Hindus are the least in literacy (13%), and Christians the most literate (29%), the Muslims coming in between them with 20·5%. The high value of literates among Christians is due to the advanced state of women education among them. In point of general literacy Tiruchendur containing some important missionary centres, comes first among the taluks; next come the taluks of Srivaikuntam, Tinnevelly, Ambasamudram and Nanguneri, the least literate taluks being Sankaranayinarkovil, Tenkasi and Kovilpatti.

The proportion of illiterate males and females to the total population are 74·3% and 95·3% respectively. The following table gives the number of literates among males and females in each taluk :—

Taluks.	Education in 1931. No. of literates.		Literates per 1,000 of pop.	
	Males.	Females.	Males.	Females.
Kovilpatti	37,396	3,448	214	19
Sankaranayinar-kovil	24,440	1,626	184	12
Ambasamudram	26,185	4,620	273	43
Nanguneri	28,915	7,232	242	53
Tenkasi	25,467	2,331	206	19
Tinnevelly	34,907	7,908	309	64
Anjengo and Tangasseri	1,131	980	354	274
Srivaikuntam	39,328	8,834	347	73
Tiruchendur	36,236	12,994	326	103
Dist. Total	254,005	49,973	257	47
Hindus	194,077	22,115	234	26
Muslims	20,163	1,930	377	28
Christians	39,753	24,928	369	207

Life and Occupation of the People

In Tinnevelly District, Pastoral and Agricultural occupations form the most important occupations and support 24·1% of the total population (as against 28·2% of the population in the Presidency who are found to be actually engaged in agriculture). Among

DIAGRAM III

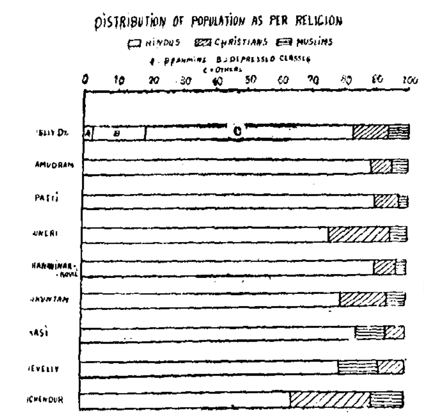
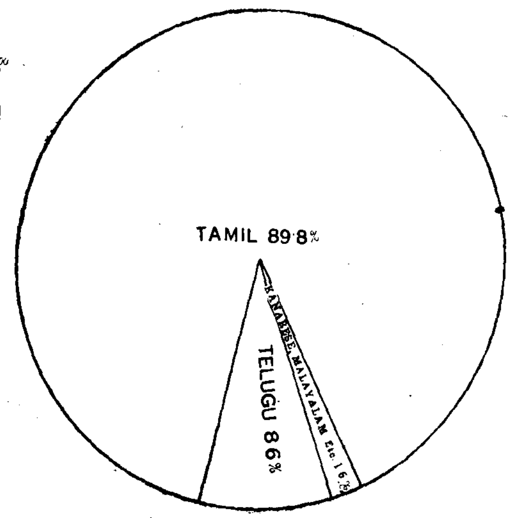
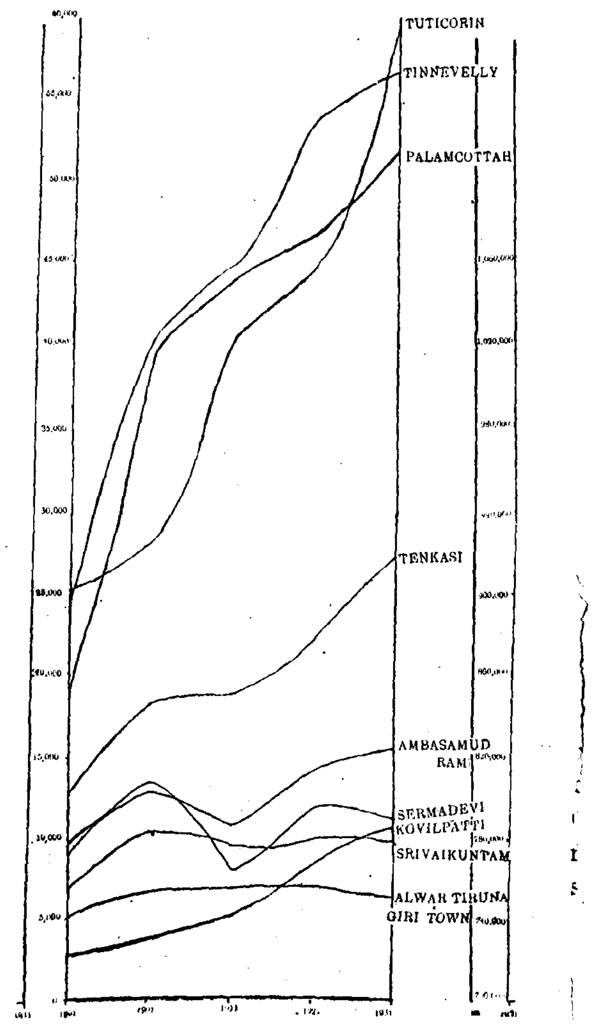


DIAGRAM IV

Distribution of population as per language.



Variation in the population of some of the towns of Tinnevelly District during 1891—1931.



the agriculturists, the cultivating landowners form 9·5% of the total population, and non-cultivating landowners only 0·8%. As many as 14,342 people were returned by the census of 1931 as being actually or partially deriving their livelihood from the palmyra.

The cotton cultivation and cotton industry provide occupation for a large number of individuals. There were in 1931 a total of 21,306 weavers and spinners as against 12,800 at the census of 1921. The weaving of cotton cloths is the hereditary employment of the Kaikkilaiyans, Pattasalaiyans and Pattunulkarans, and forms the chief occupation of a large number of Muslims.

Domestic service comes next to agriculture and employs 13·8% of the population. About 6% of the population is supported by industry while only 2·6% is engaged in trade.

According to the census of 1931, about 47·2% of the total population are non-working dependents. The large body of non-working dependents in the District, with its trade connections outside India may be due to the actual workers being employed outside the District and supporting their families at home by money remittances.

The following table shows the classification of the people in the District according to their hereditary occupations :—

Occupation.		*Pop. supported by the occupation.*	*Percentage of the Pop. to the total pop.*
Pastoral and Agriculture	..	493,379	24·1
Domestic Service	..	282,564	13·8
Industry	..	124,961	6·1
Trade	..	53,331	2·6
Others	..	1,112,672	53·4

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The 'Race' Idea, and the Present Conflict

By

Nafis Ahmed, M.A., B.E.S.,

Professor of Geography, Islamia College, Calcutta.

Racial hatred was deliberately worked up in Europe as an instrument of national policy and even before the present conflagration started, it succeeded in spreading the poison of mutual hatred among the peoples of the Continent. It went a long way in destroying good neighbourly feelings among the European states and certainly influenced the outlook of many an ambitious political party elsewhere. There seems hardly any consolation in the fact that such an idealogy of hate was utilized merely as a cover to hide ugly political and economic motives and to divert the attention of distressed millions from real issues to vague and vain-glorious idealism. To the protagonists of the 'race' idea, the conception of the 'human race,' 'the brotherhood of man,' and the like notions relating to the common destiny of mankind, are a misreading of the evolution of human society. They can only visualise 'blood groups' which have been engaged in a ceaseless struggle to obtain places in the sun!

Thus it was that an aggressive fascism exploited the idea to justify its brutality and ruthlessness.

Nazi Racial Theory.

By a curious turn of events a people of Europe, whose contributions to modern scientific thought speak for themselves, are to-day the most ardent upholders of the *race* idea. To the Nazi philosophers it is the revelation of a new religion, which, all other so-called scientific notions and religious gospels had criminally shut out from the minds of men (to the detriment of the Germans!); according to them a people is a 'unity, totality and value' only to the extent that it incarnates a superior race. Herein lies the purpose of the racial state—the 'race' is the pivot of common life and certainly an instrument to beat the 'inferiors' out! The 'race' is to be kept pure at all costs and for Germany the race can mean only the 'Aryan' or the Nordic race. Alfred Rosenberg, the Director of Culture and the brain of the Nazi party declares that 'the belief embodied in the sublime knowledge that Nordic blood represents that mystery which has replaced and vanquished the ancient sacraments' should be the Gospel. If it is suggested that perhaps, except in very tiny localities, nowhere in Germany did there exist a 'Nordically' pure race, then the 'racial' megalomaniac is ready with his retort—by careful selection the Germans could again be 'Nordicised' (what about the horses and pups—and dear intellectuals, you forget the great Spartan ideals!).

Task of the Geographer and the Anthropologist.

What is the answer to such sheer nonsense? The Geographers and the Anthropologists scratch their heads and fall back upon the resources of their sciences. To them who have had their training in the School of Scientific inquiry, free conscience and rational approach, the topic sounds like the best joke in the garden of racial humour! Then what is their answer? Certainly racial prejudice is another name for ethnological ignorance. The Social Sciences are being challenged by forces of reaction. And the totalitarian states have gone to amazing lengths in making perverted use of anthropology and sociology in advancing their views. According to Professor Griffith Taylor, geographers could do yeomen service to humanity by clarifying some of these issues by teaching tolerantly and scientifically what is becoming known as cultural geography. It will help to clear conceptions in drawing the much-needed distinctions between race, nation, language and religion, which are too often imperfectly grasped.

The Meaning of Race.

What is then the meaning of *race*? Can we speak of races as pure? What are the racial distributions of Europe? And who are the Nordics?

The origin of the word *race* is unknown, according to the late Dr. Herschfeld; some etymologists look upon Spain as its first European home, declaring that the Moors brought it thither, since they have a word 'ras' which means 'origin' or 'source'. Others derive it from the Latin 'radix' a 'root', and yet others from the old High German 'reis' which meant a line or fissure or cranny. This would connect it with the English 'raze.' But these are little better than speculations. Race can be said to be a biological term indicating major groups of people who share a common descent and hence display some similar characteristics.

These characteristics, so far as they are physical and not mental may be such external features as the colour or quality of the hair, the colour and the form of the eye, the shade of the skin and the shape of the nose. The external characteristics are easy to study, as many of them are visible at first glance. Due to this simplicity, the popular classification into the white, yellow, red and black races had long been continued. But such external characteristics are poor guides to ancestry as they are susceptible to varied changes under the influences of geographical environment. The influence of 'Climate is most far-reaching, for example dark coloured people predominate in hot climates and fair skinned people in lands that are cool and cloudy' although complexion and climate do not always agree. Certainly as far as external traits are concerned it is difficult to draw the line between the influences of geographic environment and race, and they are, therefore, a poor guide in determining biological relationships.

Head-form provides a better criterion for race, because of the preservation value of the skull and the facility of studying human remains from past ages. Thereby the past can be compared with the present although the correlation between head-form and mental traits is slight and no study of bodily traits has yet gone far in showing any relation between race and innate ability. It is amusing to note mental differences between closely related individuals, or even between selected groups of people within a given race, are much greater than between any two living races as a whole.

All are agreed (with the exception of the racial maniacs!) that pure races in the form of great groups of people, exhibiting the same physical characteristics and the same biological descent no longer exist. The world has now come to be inhabited by all sorts of mixtures of races, who are really highly diverse, and it is perhaps by averaging together a great number of individuals or by classifying them into types, that outstanding racial tendencies of different groups are recognized. 'Hot-house' produced 'races' are there certainly none and the myth of racial superiority vanishes before the logic of environmental influences.

Peoples of Europe.

How was Europe peopled? Very little is known about the earliest inhabitants. Geologically speaking, in that early period of human activity much of Northern Europe, including Scotland, Northern England, the Low countries, Denmark, North German, Polish and Russian plains, Scandinavia and Finland, were covered over with the huge ice-sheet, which retreated and advanced several times, before finally disappearing. The Heidelberg skull from Germany and the Piltdown skull from England indicate a primitive human type with ape-like jaws and powerful physique. Then came the Neanderthal man with long heads and broad noses, very much similar to the Australians and the extinct Tasmanians. The tall Cro-magnon man inhabited much of Western and South-Western Europe during the next period and has left a legacy of wonderful cave-paintings reflecting his high talents.

Then began a unique infiltration of new-comers to Europe from the heart of Asia and ushered in the period of the great migrating intruders who can be divided into three groups, regionally—the Mediterranean race in the south, the Alpine race in the centre and the Nordics in the north. Indeed, the change in climate from the rigours of the Ice-age to increasing mildness, must have exerted a 'push and a pull' upon these early peoples in the grassland interiors of Asia. The push from behind was, doubtless, due not only to increasing drought but also to growing density nearer the centres of the deserts. The pull in front was due to the attraction of the new ice-free unoccupied lands, which were gradually passing out of the grip of the glacial climate in Europe. No one can tell whether the pull was stronger or the push, but the passing away of the Glacial period presumably caused migrations into Europe to follow different paths at different times, according to the suitability of regions for human existence and the ease of movement dependent on relief.

The Mediterranean race was the first of the three main migrating (racial?) groups to reach Europe, probably via North Africa from Asia. These people were characterised by long heads, medium stature and dark hair and eyes, spread over the whole of the Mediterranean basin and extended through France into British Isles and even to Scandinavia. The Alpine group of intruders had broad heads, stocky build, short stature with dark hair and dark to greyish eyes. They chiefly penetrated into Europe north of the central mountains, spreading over to the Balkans, the Danube Valley and the Alps. They intermingled with the Mediterraneans over the plains of France and the lowlands of the Po. They later on pushed on to Spain, British Isles and Norway. The Slavs are very largely their representatives in much of Russia and the Balkans. The Nordics were the youngest group of intruders with long heads, fair hair, blue eyes and were tall. Many of their physical traits were developed in the environment of North-Western Europe. Later, the Nordics likewise spread to many directions. A body of Nordics, the Russ, migrated from Scandinavia to Russia (but according to the Nazis, the Russians are inferiors!) and gave their name to that country. They settled even in British Isles, Normandy and Iceland.

Thus, the area which we often call 'the Germanic lands' (Austria and the Sudetan areas of Czecho-Slovakia included) has been a cockpit of racial admixtures, chiefly the Alpine and the Nordic. In fact in coming to Europe these so-called racial groups have actively shoved one another aside, interpenetrated and mixed. With the change in environment, they have suffered mutation, their complexions, stature and figures have undergone radical changes. In Europe a noteworthy change has been the evolution of blondness in the North-west both among the Nordics and the Alpines. And similarly environmental influences have gone far, in all parts of the world, in marking their stamp on diverse human groups.

Exploding the Myth.

Magnus Hirschfeld, one of the leading modern sexologists in a comprehensive exposition, supported by elaborate investigations has exploded the myth of 'Nordic superiority' and its plenty of geniuses. Taking the example of the allotment of the Nobel Prize he says, "All such lists when made without bias, will show that persons of genius and persons of outstanding talent are not set apart from the rick by any peculiarity of stature, by their complexion, or the colour of the eyes, by a peculiar shape of the skull or the nose, by any ethnological characteristics whatever. What is decisive in human beings is not 'race', but individuality. A great individual, a 'genius' can appear anywhere and at any time as the outcome of a lucky assortment of gemes and an upbringing in a favourable environment." Thus science has long since exploded the mythical superiority of the Nordics or the 'long heads.' With a belief to the contrary the 'Germans' will have to dispense with such 'inferiors' as Luther, Beethoven, Nietzche, Goethe, Bismark and above all Hitler! For such luminaries of 'Nordic blood group' come from southern areas of acute intermingling in Germany—what an irony!

Why Racial Megalomania?

One might ask, why all this 'racial' megalomania? Germany! Hitlerite Germany to-day believes all its activities to be dictated by the need for self defence. Certainly the most provocative doings of the Third Reich are the outcome of defensive reactions.

It is usual for the people in a 'bad way' to ascribe their troubles to the criminal intentions of others. After the exhaustions and disappointments of the War, the humiliations of Versailles, the miseries of inflation and widespread unemployment, Germany was in an explosive and catastrophic mood ready to accept a leadership blindly. The reactionary leadership needed an 'idea' to cover their economics'—ruthless suppression at home and naked aggression abroad. 'Racism,' provided such a safety-valve and a means of release. Goebbels calls it a 'discovery', but certainly it was a clever 'invention.' Thus 'Racism' like war made it easy to hunt people out of their positions, deprive neighbouring regions of their freedom and reap the harvest of economic loot, all the time singing the hymns of hate punctuated with jingoistic utterances and celebration of victory. In his 'Racism', Hirschfeld points out: "It was possible for mass selfishness to parade behind the respectable mask of patriotism or Nationalism. Under racist auspices, too, it became easy for self-seeking to take the name of eagerness for public welfare. Internal and external hindrances to the cult of egoism having been removed, the apostles and energumens of racism in all good faith give free rein to impulses of which they would be ashamed did they realize their true nature—selfishness has been rationlized."

The Future !

Then what is to be done! The poison of racism is eating into the vitals of broader human understanding. The law of the jungle is prevailing. The goal of mankind seems to be a death struggle between warring groups—'superior races!' The 'racists' instil megalomania and intolerance into the minds of children, awakening prejudices which sooner or later would lead to strife at a scale which even the barbaric ages had not witnessed. Our immediate objective is a world of peace and it behoves us to counter-act the pernicious attempts of the false prophets.

Subjects like Modern Geography, sociology and anthropology are vital to such an education which must lead to a sympathetic understanding of world problems, especially those involving other nations and cultures. They dispel hatred and build up a free conscience—a preliminary to solve the problems of mankind. Thus when the agonies of the present conflagration are ended, education must primarily aim at the creation of an international citizenship which alone would succeed in saving a warring humanity from barbarism and destruction.

Select Contents

The Geographical Journal: June 1940.

Karakoram, 1939—By Eric Shipton.

Surveys on the Roman Frontier in 'Iraq and Transjordania—By Sir Aurel Stein.

Fact and Function in Anthropology—By J. H. Hutton.

The Geographical Journal: July 1940.

Botanical and Geographical Exploration in the Assam Himalaya—By Kingdon Ward.

Primitive Tribes in Madagascar—By Olive Murray Chapman.

Notes on the Northern Sea Route—By Professor Kenneth Mason.

The Geographical Journal: August 1940.

The West Indies in 1939—By Lord Moyne.

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Ibn Khaldun's Prolegomena to History (*Trans.*)—By Abbas Ammar.

Irrigation in the Canterbury Plains—By Margaret F. Davies.

Children's Maps: An Experiment—By Ethel David.

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The Gold Thread Industry of Surat—By A. B. Trivedi.

A Sociological Study of the Kolis in Kathiawad—By B. L. Mankad.

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All-India Soil Survey.
Soil Map of India.

Indian Information : August 1, 1940.

India's Pearl Farms.

Indian Information : September 1, 1940.

Paper Manufacture in India.
Madras Fuel Forests are being Regenerated.

News and Notes

Four ordinary meetings of the Association were held during the third quarter of the year. In the first two of them, held on 27th July and 3rd August respectively, Rao Bahadur K. N. Narasimhacharya (Asst. Director of Survey) delivered two lectures on *Topographical Surveys* and *Cadastral Surveys.*

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In the third meeting held on 31st August, Mr. M. Subrahmanya Aiyar spoke on *The Defence of India* : *A Study in Historical Geography.* In the fourth meeting, held on 14th September, Dr. S. M. Hussain Nainar (of the University Department of Oriental Research) delivered a lecture on *Arab Geographers of India.*

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In this issue of the Journal, the papers on *Sugar* and *Red Hills Lake* are concluded; and some of the remaining papers of the Tinnevelly Conference such as Paddy Cultivation, Population, Trade-centres and Communications are included.

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The 11th Geographical Conference of the Association will be held at the Rishi Valley in Chittoor District during next summer; and along with it a Summer School of Geography will also be conducted there. It is not yet decided whether there would be a separate Summer School at Saidapet also.

* * * * *

Four important Resolutions were passed at the business session of the Tinnevelly Conference, the first of which regarding the conversion of the Associate Members of the Association to Ordinary Members has been approved by the Executive Committee; and steps are being taken to have the rule altered before the next General Body Meeting.

* * * * *

As regards the other three resolutions—about the separate entry of the History and Geography marks in the S.S.L.C. book, the increase of the time for the question paper, and the inclusion of the World Regions for S.S.L.C. Public Examination—a copy of the resolutions has been submitted to the Board for consideration and necessary action.

* * * * *

We are glad to note that Mr. V. Kalyanasundaram, M.A., L.T., Dip. in Geog., has been appointed Junior Lecturer in the University Department of Geography, Madras.

* * * * *

While none of the Colleges in Madras (except Queen Mary's) has started Geography, it is gratifying to learn that two colleges in Mysore State (at Mysore and Bangalore) have opened Geography at the Intermediate stage this academic year with the idea of continuing it in the degree course.

* * * * *

Of course, Aligarh stands pre-eminent with its well established M.A. and M.Sc. courses in Geography—thanks to the pioneering zeal and spade work of Dr. I. R. Khan of the U. P. Educational Service and the untiring zeal and steady work of Dr. S. M. Tahir Rizvi.

* * * * *

Dr. Rizvi is the President of the Geography and Geodesy Section of the Indian Science Congress Session to be held at Benares in January next. We are glad to learn that a good number of interesting papers have been contributed for this section—several from this province.

* * * * *

The All-India Federation of Teachers' Associations will meet at Udaipur from 27 to 30th December 1940. Teachers from South India who intend to attend the Benares Session of the Science Congress can make it easily convenient to attend the Udaipur Conference also on their way.

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Reviews

Food, Clothing and Shelter Geographies: *Book 8—The World for Senior Students*. By McD. Robison. (Macmillan and Co., Ltd). 1940. Price Rs. 2—4—0.

In reviewing the earlier books in the Primary Series in a recent issue of the Journal, we had pointed out that the central aim of the whole series has been to bring out man's efforts to obtain food, clothing and shelter, as indicated in the general title. "The pupils observe sparsely settled areas in their own neighbourhood. They apply their growing geographical knowledge to studying where and why man lives in small numbers and in large numbers in different parts of the world". This aim is more fully developed in the books of the Post-Primary Series of which the volume under review is one. These show the relationship between land forms, vegetation, climate and distribution of population.

In this eighth book of the series, there is a more advanced treatment of the World for Senior Students than in Book 7. The plan of the volume is as follows:—The first five lessons deal in order with Landscape, the Hydrosphere, the Atmosphere, Land Forms and Vegetation and Animals. The 6th lesson deals with the Major Climatic Regions of the World under the subdivisions (which are further subdivided) of Tropical Climates. Intermediate Climates, Polar Climates and Mountain Climates. The last three lessons treat about Man's Occupations and Settlements, Transport and Trade and Geographical Regions. The volume is well got-up and finely illustrated with numerous choice pictures, sketch-maps and diagrams; and as in the Primary Books of the series the exercises in Part B of each lesson serve both for revision and further work.

The Complete Geography Series: *The World*; *The Complete Geography Series*: *The Americas.* By Alys. Mamour. (Macmillan & Co., Ltd.), 1940. Price Sh. 4 each.

The above are two of the volumes in this series designed to provide a complete course in Geography for pupils aged eleven plus. The volumes are self-contained so that they can be used independently also.

The series comprise the World as the Introductory book and three "gores" of the world in order—the Americas, Asia and Australasia, Europe and Africa. The first two alone are under review here. The key-note of the series may be summed up in the words Realiability and Readability; but special mention should be made of two of the noteworthy features such as the exercises at the end of each chapter and the many short excerpts from travel books and authoritative volumes arranged and inter-woven as part of the text. In fact the latter feature is unique and characteristic of the volumes—serving to sustain interest, enabling pupils easily to follow and enjoy the facts presented.

Other important points in the series are the specially prepared maps, the numerous valuable illustrations from authoritative and reliable sources, suggestions on geography games, handwork and local study, and a *balanced* treatment of the various countries. Each of the volumes forms a complete course indeed.

The World and Ourselves. By Elsie White. (W. & A. K. Johnston, Ltd.).

This is a superb volume of World Geography for Children treated regionally in a simple descriptive way. Starting with the Lands of Ice and Snow, the child is taken round through Mountain lands, Lands of Corn and Cattle, of Fruit and Sunshine, of Sun helmets and Mosquito nets, Lands of Wind, Rain and Rice (India, China and Japan), Lands using Steel and Concrete (Britain, U.S.A., and Western Europe)—and brought to the neighbours of Britain, closing with the chapter on "London Calling the World." Altogether a splendid introduction to World Geography for Children with attractive get-up, bold print, fine pictures and useful maps. Provision is made at the end of each chapter for varieties of practical work including handwork and suggestions for further study.

A Map Book of North America: For Middle and School Certificate Forms. By A. Ferriday. (Messrs. Macmillan and Co., London). Price 1/9d. paper cover; 2/- cloth.

The teaching of Geography in schools has now-a-days ceased to be the dull, mechanical, bookish thing it was; and among the factors that contributed to it have been books of the type under review.

This Map Book of North America follows the plan of the previous books of the series, reviewed in earlier numbers of the Journal, namely that of presenting the main geographical features in map form with accompanying text on the opposite page. The questions included at the end of each lesson serve to test the pupil's capacity for illustrating his answers with sketch-maps. They include those taken from school certificate papers, being intended for school certificate forms, though the more straightforward ones might be attempted by pupils of middle forms.

Exact Knowledge Tests in Geography: The British Isles. By R. V. Taylor. (W. & A. K. Johnston, Ltd., Edinburgh).

This set of 7 outline maps of the British Isles, showing Towns, Rivers, Landmasses and Headlands, Islands, Seas, Railways, Coalfields, Industries, etc.—complete with answers, enables a simple accurate method to be applied in testing knowledge of map positions. These tests enable the teacher to test, mark and analyse as speedily and efficiently as in testing mental arithmetic with a great saving of time and energy for him, at the same time giving him an accurate and comprehensive record. The use of these tests in schools is strongly recommended for the reasons stated.

Journal of the University of Bombay, July 1940. Vol. IX (New Series), Part I, History, Economics and Sociology Section.

This useful volume contains besides several important historical articles, the following articles that may be considered to be having a geographical bearing though they are primarily of an economic nature:—Kathiawar Ports, Coir Industry and Trade in the Malabar Coast, the Gold Thread Industry of Surat and A Sociological Study of the Kolis of Kathiawad. In the article on Kathiawar Ports, Prof. R. D. Tiwari discusses the location of the several ports, facilities offered by them, artificial extensions, services regarding shipping and goods with statistics of recent years showing competition between the ports themselves and closes up with an indication of their future.

Books and Journals Received

The World and Ourselves: By E. White.
Exact Knowledge Tests in Geography: *The British Isles*: By R. V. Taylor.
Studies on the Chemistry and Biology of the Slow Sand Filters at the Madras Water Works: By S. V. Ganapati.
The World for Senior Students: *(Food, Clothing and Shelter Geographies, Book 8)*. By L. McD. Robison.
The Complete Geography Series: *The Americas.* By Alys Mamour.
The Complete Geography Series: *The World.* By Alys Mamour.
A Map Book of North America: By A. Ferriday.
The Upper Cretaceous and Lower Eocene Beds of India: By L. Rama Rao.
The Co-operative Villages of Palestine in 1938.
Issledowania—Photometry and Sensitometrii, Book I (Moscow).
Issledowania—Kartografii (Moscow).
Issledowania—Geodessi (Moscow).
Trudia: *Centralanogo, Navno Issledowatelskogo*: *Books* 30, 31 *and* 33 (Moscow).
The Educational Review: June, July and August 1940.
South Indian Teacher: June, July and August 1940.
Journal of Indian History: April 1940.
Southern India Commerce: June, July and August 1940.
Indian Information: July 1, July 15, August 1, August 15, and September 1.
Quarterly Journal of Mythic Society: July 1940.
Kalaimagal: July, August and September 1940.
Journal of the University of Bombay: July 1940.
The Indian Journal of Political Science: July-Sept. 1940.
Geography: June 1940.
The Geographical Journal: June 1940.
Geographical Review: July 1940.
Indian Co-operative Review: April-June 1940.
Visvabharathi Quarterly: Aug-October 1940

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