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length of this area is 450 feet by 20 feet in width. The total place measurement that it was proposed to remove was 25,510 cubic yards. The total scow measurement removed was 150 cubic yards. The total place measurement removed by wave action, current action, etc., was 11,773 cubic yards."

It is apparent from Mr. Wilson's figures that the removal of the 11,000 odd cubic yards not touched by the dredge was accomplished by natural agencies after the original bed had been disturbed.

A record of weather conditions at Cobourg kept by the inspector of dredging during most of the period between the dates of the two surveys on which the estimates of bar erosion are based, may be summarised as follows:—The record begins 8th August and terminates 11th October. A heavy sea is reported on fifteen days, accompanied during four days by south-east or south-west winds. "Rough weather" on fourteen days, and winds on six days are recorded. Only six days are reported as fine. There is for several days no record, but the period was in general evidently a stormy one. The weather conditions were most favourable for the development of strong near-shore currents and vigorous wave action. Under ordinary conditions these agencies would presumably have added to the volume of the bar at the harbour entrance. The removal, however, of 150 cubic yards of the bar by the dredge resulted in substituting erosion for accretion. Such a relatively large result as the removal of 11,000 cubic yards induced by the abstraction of 150 cubic yards of material by the dredge is hardly less surprising than the changes brought about in certain chemical solutions by catalysing agents which themselves take no direct part in the reaction which they induce.

THE GEOGRAPHICAL DISTRIBUTION OF COMMERCIAL TIMBER IN THE PACIFIC STATES OF NORTH AMERICA AND ITS SIGNIFICANCE TO THE LUMBER INDUSTRY.¹

By H. M. SPINK.

(*With Sketch-Map and Illustrations.*)

THE forest area of the Pacific States of North America has been often stated to represent one of the very few remaining areas of virgin forest in the world—at least so far as the valuable softwoods of commerce are concerned. Until about half a century ago, this area was unexploited, but at the present time it is fast disappearing under the attack of lumber-camp and saw-mill. This paper proposes to consider briefly this forest area and its principal constituent trees, and to give some account of the factors influencing the distribution of the chief forest types.

The two main controlling factors in the distribution of tree types

¹ A paper read before Section E (Geography) at the Edinburgh Meeting of the British Association.

are climate and topography. So far as the Pacific Coast is concerned, the topographical features can be described as consisting essentially of a series of more or less parallel and continuous mountain chains between which lie extensive valleys or high plateaux. Of these lines the most westerly can be traced northwards from Los Angeles through the Coast Ranges of South California, the Klamath Mountains of North California, the Olympics of Washington, and then through the fringing islands from Vancouver to Alaska. This northerly portion of the chain is partially submerged. A second line is traceable from the south of the Sierra Nevada northwards through the Cascades and is continued, over the border, in the Coast Ranges of British Columbia.

Between these two mountain lines, stretching from Los Angeles to Puget Sound, is the great series of valleys—the San-Joaquin-Sacramento and the Cowlitz-Willamette. Of the two mountain lines described, the more westerly is considerably lower than the Cascade-Sierra Nevada line, and therefore the oceanic winds are little obstructed in their passage inland.

North of Puget Sound we have the coast ranges practically on the seaboard, and behind them an immense plateau area, deeply seamed by river valleys and stretching eastwards to the slopes of the Selkirks, the Gold Ranges, and eventually the Rockies. Much of this plateau has a slight rainfall, and in some parts—as in the “Dry Belt” of South British Columbia—there is actually a deficiency of precipitation.

We have, therefore, on the basis of the topography of the Pacific States, three well-defined climatic zones:—

1. The coastal strip from the sea to the crests of the most westerly mountain chain forms the first zone. Everywhere this is distinguished by the most striking equality of temperature. Points so far distant in latitude as San Francisco and Prince Rupert show a difference of only 10° F. in their average annual temperatures (*see* Table I.). This coastal strip has a very heavy rainfall, especially in the neighbourhood of Puget Sound, which lies in the track of the low pressure storms moving from the North Pacific. Thus the coastal counties of Washington, and the western coasts of Vancouver Island, have an average rainfall of from 60 inches to 180 inches. Another important point is the rapid increase in sunshine hours from north to south. These vary from 1830 hours per year for Prince Rupert to 5621 hours for San Francisco. The amount of light is an important factor in tree growth.

2. The valley areas south of Puget Sound, together with Eastern Washington and the Interior Plateau of British Columbia, form the second zone. The leading characteristics are: (1) a generally more extreme range of temperatures, varying from 1° F. January average for Atlin to a 81·7° F. July average for Merced; (2) a marked decrease in annual precipitation: 11·3 inches for Atlin, 12·5 inches for Okanagan, 10·8 inches for Merced; (3) a generally much greater amount of sunshine than on the coastal strip (*see* Table II.). In this area, therefore, the conditions of temperature and moisture are much less favourable to tree growth than on the coastal strip, and continuous forest is rarely found.

3. The slopes of the Selkirks and Rockies, the mountains of Idaho

and Eastern Oregon, together with the Sierra Nevada, form the third zone. Here climatic conditions resemble those of the valleys, but rainfall (and snowfall) is much greater. Temperature conditions, while not so equable, are generally favourable except at high elevations. Great extremes are often found (*see* Table II.). Thus climatic conditions in the valleys and plateaux, and in the easterly mountain region, resemble each other and are distinct from the average conditions on the coast. It is therefore easy to distinguish between "Coast forest," which is confined to the coastal strip, and "Interior forest," which occurs in the valley, plateau, and eastern mountain region outlined above.

This division of the Pacific forest is important, not only because the differing conditions of climate favour the growth of different tree types and different forest densities, but also because the natural barriers of the north and south trend of the mountains tend to determine the natural markets for Pacific lumber. Thus it is the Coast forest which (north of the Golden Gate) supplies the ever-increasing sea-export trade, while the timbers of the Interior forest find a rapidly growing market in the Middle West.

The Pacific forests (including Alaska) cover an estimated area of 300 million acres. So favourable are the forest conditions that they contain over 50 per cent. of the total merchantable timber of the continent of North America. Of this the Coast forest contains 60 per cent. of the total stand of timber, *i.e.* 30 per cent. of the valuable timber of North America. These Coast forests are mainly composed of four trees—Western Red Cedar, Western Hemlock, and Douglas Fir, together with Sitka Spruce, which occur in varying groupings according to climatic conditions:—

(1) In the Douglas fir type this tree and red cedar form 50 per cent. of the stand. This forest type is found only in areas where the maximum rainfall is less than 75 inches, with a very slight snowfall. Its greatest development occurs where the total precipitation is between 50 inches and 60 inches. The Douglas fir demands more light than any other associated tree, and therefore gives way to others more tolerant of shade in areas of greater rainfall. This forest type is found from sea-level in North British Columbia up to 3000 feet in its southerly extension about the Oregon-Californian boundary.

(2) Farther north the Douglas fir type is replaced by the red cedar type, in which the cedar becomes the predominant tree. Even in the south this type replaces the Douglas fir type at the higher elevations. Red cedar supplies 50 per cent. to 60 per cent. of the stands; western hemlock, which is extremely tolerant of shade, 25 per cent.; and the balance is made up of Sitka spruce and balsam.

(3) Throughout the area occupied by types 1 and 2, a third, named the hemlock-spruce type, is found. These trees supply 40 per cent. and 30 per cent. respectively of the stand, and become especially prominent in North British Columbia and Alaska. The type scarcely ever occurs at elevations greater than 1000 feet, and is usually at its best below 500 feet. Rainfall in the areas in which the type thrives varies from 40 inches to 115 inches, with an average of 75 inches.

This forest type is most important for the wood-pulp industry. All its constituent trees are used, the most important being the hemlock, which supplies 60 per cent. of the total wood used in the Pacific pulp industry. The industry is confined to the forests of the Coast, in

Coastal Forest, Douglas Fir type, in dense stand.

which 19 mills operate south of Puget Sound and 6 others to the north, producing 300,000 tons of paper annually. The geographical distribution of this type of forest points to a great extension of the pulp industry in British Columbia and Alaska.

(4) North of the Lynn Canal the hemlock-balsam type occurs. It prevails over wide areas in Alaska, but generally at higher elevations, and in areas of high precipitation and heavy snowfall.

(5) A fifth type—the Sequoia—occurs all along the seaward slopes of the Coast Ranges of North California and at high elevations on the Sierra Nevada. Only the redwood trees of the Coast Ranges are commercially important.

The redwood thrives best at low levels, especially on the moist coast plains. It requires humid conditions, and benefits from the heavy sea fogs of the Golden Gate area.

The tree types of the Interior forest are only sparsely represented in the valley and plateau regions, but forest growth increases as the foothills on the east are reached. Generally speaking, over the whole area lying eastward of the Coast forest, the forest types are very similar.

Heavy Forest, Yellow Pine type, Klamath National Forest, California.

They are two in number : (1) the Yellow Pine type ; (2) the Douglas Fir type (mountain form).

(1) The yellow pine type, in which the pine predominates, is found on well-drained soils at elevations of 1500-2500 feet in South British Columbia, and 4000 to 7000 feet in South California.

The western yellow pine itself is one of the most important and widely distributed trees in North America. It thrives especially well in the heat and dryness of a continental climate, and therefore the type increases rapidly in the south, and reaches its widest extension in the South-West States. It prefers sunny situations, but stands cold very well. It resists drought better than any other commercial tree, but does best where long summers are combined with a rainfall of 18 inches to 40 inches. It is extremely intolerant of shade.

In the extreme south of its range western yellow pine makes up 100 per cent. of the stands, since it thrives on a low margin of moisture. In South Oregon and North California the yellow pine type is modified by the presence of sugar pine, which often makes up 15 per cent. of the stands, though generally at altitudes of 4000 feet to 7000 feet. Sugar pine is one of the most beautiful trees in America. It is exacting, however, in its requirements—demanding abundant moisture, light, and good soils. In consequence its range is limited.

(2) The Douglas fir type of the Interior forest extends, with many variations in the constituent trees, from Central British Columbia to the Oregon-Californian border, but is most marked in Southern British Columbia and in Eastern Washington and Idaho. Southward of this the type merges into the yellow pine type. In virgin stands the Douglas fir composes 60 per cent. of the trees, but where the original forest has disappeared, either from fire or logging operations, the fir is replaced by lodge-pole pine. The Douglas fir type thrives best at altitudes of 2000 feet to 4000 feet, with a precipitation of 18 inches to 40 inches. Above 4000 feet lodge-pole pine predominates.

In the Sierra Nevada, near the Oregon border, the forests still contain large areas of the Douglas fir type, but here, as indeed over all the area of the Interior forests, the types often vary very much in their constituent trees. Nowhere in the Interior forests is there found the very definite location of types such as is found in the Coast forest.

In the Idaho forests such associated trees as western larch, white fir, lodge-pole pine are frequent, while farther south the stands include western yellow pine, cedar, white fir, sugar pine.

The relation of the Pacific forests to the economic life of the central and eastern portions of North America becomes more important each year. Since the opening of the Panama Canal their significance to Europe as sources of supply has increased also, and in addition they continue to gain in importance as a source of supply to Australia and the Far East. Each year, therefore, sees an increasing demand made upon the forest resources of the Pacific States of North America.

The result has been ruthless and uneconomical exploitation of forest areas, an abnormal expansion of the lumber industry in the West, with a constant state of insecurity in the industry. But the results to the community are more serious, because exploitation of such a nature leads to (1) a continual shifting of the centre of the lumber industry; (2) a steady increase in the proportion of transport costs as the lumber centre moves; (3) a great increase in the price of lumber; (4) the disappearance of the more valuable tree types, since these are cut first and seldom replanted.

The constant shifting of the lumber industry to areas increasingly remote from the timber markets is particularly serious. In the early forties of the last century lumbering centred in New England. In 1850 New York was the leading lumber state. Ten years later Pennsylvania led. Then came the period when the "Lake States" were the centre of

the industry. These reached their maximum output in 1892, and then rapidly declined. Now the region produces only one billion board feet and scarcely controls its local market.

In the seventies the Gulf States took the lead and reached their maximum production in 1909. At present they still lead in the total out-

FIG. 1.—Timber output of (1) Lake States, (2) Gulf States, (3) Pacific States in the period 1860-1920.

put, but, as the chart (Fig. 1) shows, the Pacific forest is rapidly superseding them.

The same thing is true of the forest area of Eastern Canada, where, although forest exploitation has never been so intense as in the U.S.A., the leadership in production is inevitably passing to the Pacific. Since 1900 the Pacific forests have been actively exploited. At present there is an annual cut of 11 billion board feet, to which must be added $1\frac{1}{2}$ billion feet lost as a result of fires or other causes. The regrowth

is estimated at $3\frac{1}{2}$ billion feet. Therefore the annual destruction equals more than three times the reproduction, though, of course, as much of the area is virgin forest where regrowth is slow, the reproduction would be much greater in replanted areas. But even so there is a serious difference between the amounts cut and the reproductive capacity.

When the full effect of the increasing demands likely to be made upon the Pacific forests is felt, the question of the "life" of the forest is seen to be very urgent. The "home" market in the States is being rapidly extended owing to failing supplies from the older lumber centres (Fig. 2).

This map shows (incidentally) how serious is the transport factor, since the market is steadily becoming more distant from supply. Quite apart from the physical difficulty which the railroads must face in moving an ever-increasing volume of lumber from the West, it is found that the percentage of the lumber costs absorbed in freights has risen from 12.5 per cent. in 1905 to 15 per cent. in 1910 and 28 per cent. in 1915. The question has aroused very serious attention in North America, and the U.S. Senate called for a special report in June last year.

Almost as important, so far as absorption of Pacific Coast lumber is concerned, is the growing export overseas. The opening of the Panama Canal merely accentuated an increasing sea traffic in Pacific lumber. The overseas markets in order of importance are Great Britain, continental Europe, China and Japan, Australia and South America. If we eliminate the War years, the tendencies of the export trade become clear, except that the rapid advance of the European market is altogether since 1915 when the Canal's influence made itself felt. Thus since 1900 the Chinese and Japanese market increased by 350 per cent., the Australian by 300 per cent. and the South American by 300 per cent.

The total foreign shipments in 1913 totalled over 600,000,000 board feet.

How great the demands now being made upon the Pacific forest area are, is sufficiently obvious, and in view of the short life of the other American forest regions we may expect some kind of control over the lumbering operations in that region. At any rate, the question is being seriously debated in the Canadian and American legislatures at present.

TABLE I.—METEOROLOGICAL CONDITIONS ON THE COASTAL STRIP.

	Average Temperature in Degrees F.			Rainfall in Inches.			Ann. Sunshine.
	Jan.	July.	Av. Ann.	Jan.	July.	Av. Ann.	Hours.
Prince Rupert (50), . .	38	50	44.8	135"	1.97"	86.58"	1830
San Francisco (100), . .	49.5	57.3	54.9	5"	0"	23.25"	5621

Fig. 2 —Sketch-map of United States to show the extent to which the home market is supplied by timber from the Pacific States.

TABLE II.—METEOROLOGICAL CONDITIONS IN THE AREAS OF INTERIOR FOREST.

Interior.	Average Temperature in Degrees F.			Rainfall in Inches.			Ann. Sunshine.
	Jan.	July.	Av. Ann.	Jan.	July.	Av. Ann.	Hours.
Atlin (2240), . . .	-1	53	30·5	1·01	1·08	11·34	...
Quesnel (1700), . . .	14	62	39·7	1·57	1·77	14·78	...
Okanagan Val. (1200), . . .	20	66	44·7	1·2	1·1	12·5	2134
Spokane (1891), . . .	27	69	...	...	...	18·85	...
Merced (173), . . .	47	81·7	...	2·35	0	10·8	6460
Cascade Sierra Line.							
Stuart Lake (2280), . . .	7	55	33·3	1·57	1·53	15·75	...
Glacier (4000), . . .	14	57	35·7	8·61	2·97	60·11	...
Weaverville (2160), . . .	34	70·4	51	7·89	·38	38·49	...
Napa (20), . . .	46·9	67·6	58	...	...	...	...
Placerville (1875), . . .	59·9	100·8	78·3	8·71	·02	44·45	...
Tulare (274), . . .	58	101·2	79·6	2·93	·01	15·95	6500

Note.—The figures in brackets show the heights of the stations above sea-level.

TABLE III.—TIME OF REPRODUCTION OF TREES OF MERCHANTABLE SIZE.

W. Yellow Pine	}		120 years.
Douglas Fir			
Larch			
Spruce			
W. White Pine	}		100 years.
W. Red Cedar			
W. Hemlock			
Lodge-pole Pine			140 years.

GEOGRAPHICAL NOTES.

EUROPE.

Archæology and the Ordnance Survey.—The most interesting point in the *Report* of the progress of the Ordnance Survey to 31st March 1921, which has been recently issued (Cmd. 1308), deals with the subject of Archæology. On 1st October 1920 Mr. O. G. S. Crawford was appointed Archæology Officer on the staff of the Survey, and the immediate result has been great additions to the information