FORESTRY METEOROLOGY

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A Thesis

Presented to the Faculty

of the

School of Forestry

Oregon State College

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science

June 1948

Approved:

Redacted for privacy

Professor of Forestry

ACKNOWLEDGEMENTS

The author wishes to thank Mr. G. Lloyd Hayes, instructor in forest management, and Dr. Lewis F. Roth, associate professor in plant pathology of Oregon State College for their assistance in obtaining material for this thesis.

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INTRODUCTION

The pilot of an airline transport, the captain of a ship at sea and the farmer who loses his crops during a drouth truly realize the importance of weather to their industries. What about the forester? Just how important is weather to his chosen field? This report will attempt to answer these questions.

SCOPE AND PURPOSE

Forestry meteorology is considered in this report as the field of the inter-relation of weather and forestry, using forestry in its multiple-use sense. Necessarily then, the scope of this report is broad.

The purpose of this report is to arouse an interest and realization of the ways in which weather effects forestry. The coverage is not intended to be complete - just comprehensive enough to carry out the purpose.

WEATHER AND THE PHASES OF FORESTRY

The influence of weather on the various phases of forestry is briefly described under the following phase topics:

Silviculture

The effect of weather on silviculture will be divided into three parts - forest ecology, applied silviculture, and reforestation.

Forest Ecology

A tremendous amount of work has been done in correlating climatic conditions and plant growth. Very detailed studies, including the placement of pins in various parts of the tree to determine growth, have been made. Efforts have been made to isolate the various weather elements as to their individual effect on growth, but this has been a difficult task as all the elements are so closely interrelated. Much of the early work in correlation of growth and weather came to naught as average climatic conditions were used, and plants do not respond to averages but to actual day to day weather.

Work on climatic vegetative and forest zones has been done by many men including Koppen, Thornthwaite and Mayr. More detailed work has been done on climatic requirements of species. An example of recent work in this field is presented in a bulletin published in 1947 by the New South Wales Forestry Commission which lists all native species in the territory and the climatic requirements of each.(3)

That climate has an important effect on tree species is pointed out by the case of the Monterey pine (Pinus radiata.) The gradually changing climate of California since prehistoric times has reduced the once large Monterey pine forest to a small isolated one on the coast. That the climate even in this small area is not optimum for the tree is borne out by the much better growth which is obtained in South Africa and Australia in Monterey pine

plantations. The present climates of South Africa and Australia are very similar to that which was present in the prehistoric forests of Monterey pine in the western United States.

Applied Silviculture

Cutting methods used in a stand must consider climatic factors. The possibility of windthrow is often the deciding factor in determining the method of cutting used. Seed distribution depends directly on the wind, temperature and humidity. A hot east wind is most satisfactory for seeding the west slopes of the Cascade and Coastal ranges. The high temperature opens the cones and the strong wind blows the seeds well down the slopes. These east winds are much more efficient than the prevailing, moist southwest winds which often fail to open the cones. It must be remembered that each time trees are removed from the stand the local climate of the stand is changed.

The time of slash-burning is determined almost entirely by current and forecasted weather conditions. In some eastern states, burning permits are issued which are valid only if weather and fuel moisture conditions are favorable.

The possibilities of mechanical damage from ice, snow, wind, hail and lightning are important factors to consider in silvicultural practices.

Reforestation

The time of planting seedlings is largely determined

by the temperature, wind, humidity and condition of the ground. Either hot, dry winds or cold, dry winds dessicate the roots of the seedlings and make planting conditions unfavorable. If the ground is frozen, the roots do not make good contact and tend to dry out and die. Frost heaving of seedlings in some areas necessitates mulching for the establishment of the new stand. High winds may whip seedlings to such an extent that they are actually girdled.

Fire Control

Fire weather research and development has made great strides through the work of the Forest Fire Warning Service of the Weather Bureau, the Forest Fire Research sections of the Forest Service Experiment Stations and the cooperative efforts of other public and private agencies. An insight into the progress in this field can be obtained by going over a brief history of the two public agencies.

Forest Fire Warning Service

The need for weather information in fire control was realized as early as 1911 by the fire control agencies. They turned to the Weather Bureau which cooperated in giving weather information from 1911 to 1916. In 1916 the Fire Weather Warning Service became reorganized as part of the Weather Bureau activities, national in scope. In 1924 the Forest Service and the Weather Bureau began a cooperative program to intensify the work.

The present organization of the Forest Fire Warning

Service is centered at ten Weather Bureau offices: Asheville, N. C.; Boston, Mass.; Chicago, Ill.; Missoula, Mont.; Boise, Idaho; Seattle, Wash.; Portland, Oregon; Mt. Shasta, Calif.; San Francisco, Calif.; and Los Angeles, Calif. Expert forecasters at these stations distribute forecasts to using agencies throughout their regions by telephone, telegraph and radio. Self-contained, mobile truck units operate from offices in Portland, Mt. Shasta, Missoula, Boise, Seattle, San Francisco and Los Angeles. These units are available for on-the-fire forecasting on large or dangerous fires.(12)

Forest Service Experiment Stations - Forest Fire Research

Although some prior work had been done at the various experiment stations, forest fire research first started as a full-time project at the Northern Rocky Mountain Experiment Station in 1922. The work gradually expanded until there were also full-time projects at the Northeastern, Lake States, Appalachian, California, and Pacific Northwest stations. Since 1945 the Forest Service has concentrated the larger projects at the Southeastern, Northern Rocky Mountain and California stations with additional work being done at the Lake States, Eastern and Pacific Northwest stations.

The original project at the Northern Rocky Mountain Station was the study of fire danger measurements, which is still a big item in their studies. Weather conditions -

past, present and future - are major factors in measuring fire danger. Other projects which have been or are being studied are fire intensity and behavior, damage appraisal and measurement of visibility distances, all directly related to weather.

Stream Flow, Flood Control and Erosion

The inter-relation of forests and weather seems to be the most important factor in the control of floods and erosion and in the regulation of stream flow in forested watersheds.(6) Many of the early European forestry conservation practices were initiated to regulate stream flow and prevent floods.(10) In Switzerland, protection forests have been established to prevent snow avalanches in many areas.

In timbered watershed areas, the cutting practices used must be coordinated with the regulations of water supply. The weather and influence of the forest upon the weather are important factors to consider in watershed management. However, the effect of the forest condition upon water supply and quality seems to vary with soil and other conditions.(4)

Forest Insects

Every forest insect has its climatic optimum at which it grows and reproduces most efficiently. Temperature optimums vary with the species of insect and the stage of development. Generally, insects prefer meso-humid conditions. However, the powder post beetles, which attack

kiln-dried hardwood, will live only in wood which has fifteen percent or less moisture content. Thunderstorms have a distinct effect on insects, reducing the insects activity considerably. This is attributed to ozone, formed by the lightning, which will literally put the insects in a stupor. Conversely, barometric pressure drops during cyclonic storms increase insect activity.(13)

The mechanical action of climatic factors can be either favorable or adverse to the insects. Severe wind storms, such as the Olympic blowdown in 1921 or any one of the destructive southern hurricanes, provide a good breeding ground and habitat for many species of insects. In like manner, snow and ice storms injure and lower the resistance of trees to insect attack. An example of climatic conditions retarding insect development is the case of the oak looper in Oregon. In years of heavy fall rains, the number of loopers is reduced tremendously as the heavy female is unable to progress upward in the rain to deposit her eggs on the oak twigs.

Several outstanding examples of the effect of climatic factors on insects species follow.

Western Pine Bark Beetle (Dendroctonus brevicomis)

Fatal temperatures are important in both the natural and artificial control of this insect. In natural control, low temperatures of -5° to -20° will kill the insect depending on the stage of the insect development and the thickness of the bark of the infected pine tree.

Sudden drops in temperature are the most important as the insect is unable to throw off the moisture in its body and is literally exploded by the ice formed within its body. Normally, the insect is able to throw off the water in its body so that it is in a dessicated state during low temperatures and not as much harm is done. In 1932 sudden drops and extreme low temperatures caused a high mortality of the bark beetles in the pine regions of Oregon and California.

In the artificial control of the beetle in which the infested trees are felled and exposed to the sun, with or without the bark being peeled, bark temperatures of 115°F. or over are completely fatal to all stages of the beetle. On well exposed trees these bark temperatures will be reached when air temperatures are 85°F. and above. (11)

Southern Pine Beetle (Dendroctonus frontalis)

This bark beetle, which attacks all four of the southern pines, increases and decreases in numbers directly correlated with the weather cycles. The thin bark of the southern pines makes this insect particularly susceptible to low temperatures. After mild winters, the insect appears in epidemic numbers and expands its range to the north. After extremely cold winters, the insect recedes and may almost disappear from the forests. Low winter temperatures are, as of yet, the most important factor in controlling this destructive insect.(17)

Gypsy Moth (Porthetria dispar)

This introduced insect increased from a pair which accidentally escaped near Boston, Massachusetts to numbers which materially threatened the oaks and other broadleaf trees of New England. Periodically, this insect expands its range into Canada, where it prospers for a few years and then dies out. The reason for this may be attributed to the manner in which the insect lays its eggs and the weather conditions. The female moth lays her eggs at the bottom of tree trunks in jelly-like clusters. In ordinary years the egg clusters are protected from normal, fatal, low temperatures by a blanket of snow. In some years, however, the low temperatures come without snow and the eggs are killed.(7)

Forest Pathology

In general, every forest disease is controlled by climate. Each has its climatic requirements for optimum development. In the study of temperature relations to the growth of wood-destroying fungi, fifty six species were tested under laboratory conditions. Optimum temperatures for growth were found to range from 20° to 36° C., while inhibiting temperatures ranged from 28° to 46° C. There is a slight downward shift of the optimum temperature with the passage of time. It is probable that the optimum temperatures for growth under forest conditions would be lower than those determined in the laboratory.(9) Moisture requirements vary with species but generally are

fairly high for optimum development.

Infectious Diseases:

Some specific examples of the influence of weather on forest diseases are given in the following paragraphs.

Cedar Leaf Blight(Keithia thujina) This blight, although not particularly damaging, is very common on the Western red cedar of western Oregon. The interesting fact is that the disease is found only on trees in valleys and other depressions, although the light spores of the disease spread everywhere. It has been determined that the higher humidity and more even temperatures of the depressions are required for the development of the disease.

Shoestring Fungus Rot (Armillaria mellea) This root rot attacks many species, but it is particularly destructive in the pine stands of the intermountain region. In years following drouths the disease may reach epidemic stages and kill or severely damage large numbers of pine trees. The lower soil moisture in drouths aids the spread and development of the rot, and the drouth-weakened trees are more susceptible.

White Pine Blister Rust (Cronartium ribicola) Although the eradification of the ribes plants, which are the alternate host in this disease, is the main method used in controlling this disease, weather plays its part in periodically helping to prevent its spread. The spores

which travel from the ribes to infect the pine are very short-lived and the length of time thay they remain viable is directly dependent on the atmospheric humidity. Under dry conditions the life of the spore is short; while under humid conditions the life of spore is comparatively much longer.

Non-infectious Diseases

High temperatures cause several types of injury or disease to trees. Particularly susceptible to this type of damage are formerly protected trees which have been exposed to more severe conditions. Sunscald, in which blisters or cankers are formed on the exposed portions of the bark, is common on young trees exposed by the removal of old-growth in logging. Similar in nature of injury is winter sunscald which is caused by alternate freezing and thawing of the inner bark. In some species, high temperatures may cause heat defoliation.

Frost damage is caused primarily by irregular, late spring or early fall frosts during the growing season. Frosts may kill the buds or redden the leaves. Trees on which the leaders have been nipped back by frost show a characteristic bushy appearance. The cambium of thin-barked trees may be damaged enough to cause the formation of cankers. Sudden drops to low temperatures may cause frost cracks in the tree. Young seedlings may be completely severed or raised considerably in the soil by frost heaving. As a result, the seedling roots lose close contact with the

soil and are eventually dessicated.(1)

Range and Wildlife Management

From the cattleman's viewpoint, rain is the most important factor in range management.(5) The export of thousands of head of cattle from California, resulting from the drouth in the winter of 1947-1948, bears this out to a considerable extent. The amount and distribution of rainfall affects the amount of forage, the season of use as well as the water supply for livestock. Extreme weather conditions such as the prolonged blizzard in Colorado in the winter of 1947-1948 necessitate additional supplemental feeding of range livestock and cause many cattle losses.

In the same manner, wildlife in the forests are affected by weather. In several years, severe winters in the Lava Beds National Monument, California, have caused large losses in the deer herds in the area. These losses resulted in malnutrition and freezing of weakened animals. In the Willamette Valley the hatch of pheasant broods may be greatly reduced by cool, wet, spring weather. In like manner, the local hatch and season of flight of migratory fowl is controlled by weather conditions.

Logging Practices

When a good wind storm comes up in the woods, the logger is ready to pull out for the day. The chance of injury from windfalls and falling branches and the general unpredictableness of things well warrant his desires.

In this region, the seasonal distribution of log supplies on the market and the fight of lumber operators for winter shows is another indication of the hand of weather in logging. Of course the shortage of logs and available logging sites in the winter may be offset by cold decks at the mill but only at additional costs. Directly coupled with this is the effect of weather conditions on road building and maintenance. All-weather roads, which must stand the rigors of freezing, heavy rain and resulting slide possibilities under heavy use, may cost many times what a summer, good weather, road would cost.

Weather conditions may determine to a certain extent the type of logging equipment used. Generally, the cable systems can operate under wetter conditions than can "cats." The "cat" operator trying to yard logs through a morass of mud and water is neither happy or efficient.

The closure of logging operations during bad fire weather will put even the toughest logger on his knees praying for rain.

Forest Recreation

Generally speaking, the weather controls the amount and kind of forest recreation possible. Thus, it is a major factor in recreation management in forests. An analysis of tourist or recreation ads will almost inevitably show a reference to weather. An ideal climate, cool forests or invigorating forest breezes are almost by-lines in forest recreation.

Snow is a sheer necessity to the winter sports fan who can't quite get a thrill out of slaloming down a sawdust pile. The amount and kind of snow and the present weather conditions are factors which have helped establish winter sports areas such as Mt. Hood. The current increase in winter sports enthusiasts makes this phase of forest recreation increasingly important.

Camping and swimming for any but the most ardent recreationist require pleasant weather. The lack of rainfall may make the old swimming hole a little too shallow, the campground spring a mere trickle of water or the dust unbearable.

"Ugh! Last two nights cold so steelhead no run." What fishing enthusiast doesn't have his own ideas on the relation of weather and his chances of his making a good catch. Superstition or not, it is an important factor to consider in the estimating and planning of fishing use of an area at a certain time.

The snapping of a dry twig or heavy rain and dripping brush may keep the hunter from realizing his quest or may even keep him out of the woods. As has been stated before, extreme weather conditions may reduce the numbers of animals available to the hunters. In regard to hunting, even the politicians may worry about the weather. In closing forest areas during bad fire weather in this state, the governor may find the wrath of the hunters upon him. During fire closures in hunting season, local fire

protection agencies are often plagued with calls from all over the west from prospective and planning hunters.

Forestry Personnel Administration

The predominance of outdoor work in forestry makes weather particularly important in forestry personnel administration. Weather in its various ramifications exerts definite influences on human temperament and efficiency. Taken as a whole, weather determines human life zones, concentrations of populations and standards of civilization and development. Individually, the weather elements exert specific effects on humans.

It has been said that high winds preceded many of the range wars in the west. Experiments have proven that high winds, particularly hot winds, cause irritation and unruliness. They act as a stimulant to activity but usually in a detrimental manner.

Temperature changes produce varied effects on humans. Unvarying temperatures, whether high, moderate or low, cause a decrease in efficiency. A slight lowering of temperature is not beneficial, but a continued decrease provides stimulation. It is thought that the slight decrease does not activate increased circulations so that a shivering effect is produced, but that continued temperature decrease to a certain minimum increases circulation and hence activity. Brief rises of temperature to a certain maximum also provide a stimulating effect.

Efficiency is directly correlated with storm activity.

In fact, the cyclonic storms of the temperate zones are thought to be one of the main reasons for the concentration and development of civilization in these areas. It is natural to think that efficiency is highest during periods of good weather, but in reality, it is not. Continued weather of any type noticeably lowers efficiency. In the following sample storm pattern of two days of clear weather, one partly cloudy day and two stormy days, the following effects on efficiency have been noted. Efficiencies were fairly high during the first clear day but dropped during the second clear day. They remained constant through the partially cloudy day and showed a drop during the first stormy day. Efficiencies then jumped to their highest point on the second stormy day just before the storm ended.(2)

An interesting example of the effect of weather on human efficiency occured at Harvard University during the hurricane of 1938. On the day this intense storm passed over the Harvard campus, the new freshman class took their entrance examination. The results were astonishing. This class produced, by a considerable margin, the highest scores which had been achieved in the 200 year record of the tests. One noted psychologist-geographer, Ellsworth Huntington, attributes these elevated results to the abundant quantities of ozone present during the storm. He believes that ozone is a main factor in the stimulation of human activity and efficiency. He states that even

the invigorating effect of the forest may be due to the ozone produced therein.

BRIEF HISTORY OF FOREST METEOROLOGY

Most of the historical work covering the field of weather and forestry has been in the more technical and theoretical phases rather than in the broad applied fields covered in this report. This narrowed field is known as forest meteorology. The brief history of forest meteorology, which follows, will point out many phases of development of the broader field of forestry meteorology.

Early European Work

The early forestry work in Europe emphasized meteorological studies. One of the earliest bibliographies of forestry, published by Loffenholz-Colberg in 1872, was composed primarily of articles on forest meteorology in its phase of forest influence. The early foresters of central Europe used forest meteorology to obtain regulatory practices. The argument presented was that the forest had a definite effect on the climate of Europe.

After this initial work by the foresters, a new group - the geographers - contributed vast amounts of work on the effect of forests on climate. In France in this period, the emphasis was on the inter-relation of stream flow, forests and weather. From this basic work, forest conservation measures for watershed areas were developed.

On the steppes of Russia in the early 1880's an extensive shelterbelt program, similar to more recent efforts in this country, was attempted to modify the climate. Again, the foresters drew on meteorology to prove the necessity for their work.

Early American Work

The early American foresters and the conservationists used European work and theories to sell the idea of forest conservation. Here as in Europe, meteorology was called on to boost the cause of forestry.

From these early expoundings, there developed a controversy between the foresters and the meteorologists, who were just entering the field of forest influences. The meteorologists challenged the broad statements of the foresters on the effects of the forests on climate. A later development of this clash was the Wagon Wheel Gap experiment in Colorado, which was set up to study the influence of forests on climate and stream flow.

Another interest of the early forester was in the effect of weather on tree ecology. In this field the foresters borrowed much from the literature and findings of the agriculturists and botanists.(10)

Present American Work

The present work in the field of forest meteorology includes an expansion into almost all phases of forestry meteorology work. There has developed a more cooperative attitude among the different groups doing work in the

field - the foresters, the meteorologists, the geographers and others in related fields.

WEATHER BACKGROUND FOR FORESTERS

Following is a brief summary of the weather background which this author feels is necessary for the forester to have to be able to fully understand and apply the influences of weather on forestry.

Introductory Material

A fundamental coverage of atmospheric circulation, elements of weather and meteorological terms is the first necessity. Theories of weather development should be covered briefly to give the forester an insight into forecasting theory and methods.

Climatology

Climatology is probably the most important phase of meteorology to be studied by the forester. Climatology is the study of the tabulated data of weather conditions which have already happened. The forester should know where to obtain this data and in what forms it appears. It is important that the limitations of this data be understood. The methods used in obtaining the data, the completeness of the data and the time-coverage of the data are important factors to consider in determining the accuracy and usefulness of the data.

Special Phases

Mountain meteorology is a special phase which should

be understood by the foresters. The topography and elevation of the mountains cause special variances in wind, temperature, precipitation and other weather elements. Micro-meteorology, the study of the climate of a small area such as a timber stand, is also important to the forester.

Advanced Training

Those wishing to go into fire weather forecasting or some phase of forestry meteorological research could obtain extensive additional meteorological training at any one of the universities or colleges in the country which offer meteorology majors.

SUMMARY OF CONCLUSIONS

A look in the future seems to point to increased work and to the expansion of knowledge in all phases of forestry meteorology. War-time research in the field of meteorology has given much additional knowledge and brightens the possibilities of solving many of the problems of the understanding and forecasting of weather.

With this expansion of forestry meteorology, foresters will be required to understand more of this field in order to apply that which as been gained. Also, the expansion of forestry meteorological research will provide additional jobs for those interested in this field.

So, let the forester keep a "weather-eye" on the future.

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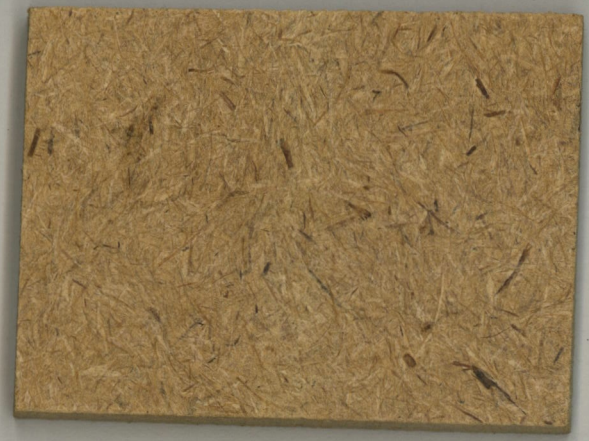

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