Bulletin 55. 1901

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

FORESTS AND SNOW

—BY—

L. G. CARPENTER.

Published by the Experiment Station,
Fort Collins, Colo.,
1901.

THE AGRICULTURAL EXPERIMENT STATION

FORT COLLINS, COLORADO.

STATION STAFF.

L. G. CARPENTER, M. S., Director	Irrigation Engineer
C. P. GILLETTE, M. S.,	Entomologist
W. P. HEADDEN, A. M., Ph. D.,	Chemist
B. C. BUFFUM, M. S.,	Agriculturist
W. PADDOCK, B. S.,	Horticulturist and Botanist
R. E. TRIMBLE, B. S.,	Assistant Meteorologist and Irrigation Engineer
F. L. WATROUS	Assistant Agriculturist
L. A. TEST, B. M. E., A. C.,	Assistant Chemist
E. D. BALL, M. S.,	Assistant Entomologist
C. H. POTTER, M. S.,	Assistant Horticulturist
*JOSEPH LOWNES, B. S.,	Assistant Chemist
F. C. ALFORD, B. S.,	Assistant Chemist
H. H. GRIFFIN, B. S.,	Superintendent Arkansas Valley Substation, Rocky Ford, Colo.
J. E. PAYNE, M. S.,	Superintendent Plains Substation, Cheyenne Wells, Colo.

OFFICERS.

President B. O. AYLESWORTH, A. M., LL. D.

L. G. CARPENTER, M. S.,	Director
A. M. HAWLEY	Secretary
W. R. HEADDEN, B. S.,	Stenographer and Clerk

---

* Died December 9, 1900.

FORESTS AND SNOW

By L. G. CARPENTER.

The intimate connection between the melting snow banks of the mountains and the agricultural prosperity of Colorado is too evident to those acquainted with the conditions of the State to need discussion, for most of the water which carries fertility to the fields and farms comes from the white-capped mountains; but even among those most interested in the agriculture of the State there have been some who have had a question as to the extent to which the forests were useful. Some have even advocated their destruction, under the supposition that the water supply would be increased.

While it is not thought by the writer that the forests materially affect the rainfall in our Colorado mountains, their influence as a protecting cover for the snow and in saving it from premature melting and the effect of winds, which increase the evaporation, is an important function. Without intending to enter upon a discussion of the question at this time, this bulletin is more especially intended to bring out some of the relations of the forests to our water supply, which have become evident in our study of one of the typical irrigation streams, and also to present some of them pictorially, in such form as to help the reader draw conclusions for himself.

For some years attempts have been made to obtain photographs which would show certain conditions, but as visits to the localities in question were usually made for other purposes, the trips were too late to be at the best time to examine the effect of the forests. It was found that it would be necessary to go earlier in order to obtain views desired, and to make trips for that special purpose. Hence, when the heavy snowfall of 1899 gave promise of remaining late enough in the summer to permit visits to the regions without interference with other work, advantage was taken of it. Correspondence had been opened with mountain friends, who with long acquaintance with mountain conditions had had unusual chances for observation. They were asked to let me know when the snow cover had so melted that the ground appeared in places, and also the places where green timber and bare spots were near together, so that the conditions could be readily compared. A portable dark-room was prepared for developing in the field. Reports that the conditions were favorable were received from three correspondents on the same day. The snow fields were melting so fast that only one section could be visited while the conditions were favorable, and this was near the headwaters of the Cache a la Poudre. Two places, some twenty mile apart, were visited. One on the divide between the Poudre River and Estes Park, and the other on the headwaters of the Laramie River. The former was visited under the guidance of Mr. John Zimmerman, who is a native of Switzerland, and who has lived in the high elevations of Colorado for nearly twenty years; the latter, under the direction of Mr. John McNabb, who has also had a long and intimate acquaintance with high elevations. The results are shown in the plates, which speak for the photographic skill and successful carrying out of instructions by Mr. J. D. Stannard, then assistant in the Department of Engineering. It is believed that no more striking series of photographs on this subject has been brought together. They enable a comparison of the conditions to be made by the reader and repay examination and thoughtful consideration in connection with the charts.

We hoped to obtain an additional series of photographs during the subsequent winter, but the character of the snowfall was unfavorable for this purpose.

A general description of the condition of the streams, as connected with the melting of the snows, is desirable as a basis for the explanation of the views.

CHARACTER OF THE STREAMS.

Colorado is moderately supplied with rain, the annual precipitation averaging about fourteen inches. In the mountain areas, the amount varies with the elevation and topographical conditions, but the increase with elevation is not marked until the extremely high elevations are reached. In these places observations are under exceptional conditions, and too few in number to form a safe guide. On the eastern slope of the mountains, the precipitation is mostly due to the easterly winds brought in by the passage of an area of low barometer to the south. The air is forced up by the mountain ranges, and cooled by the elevation enough to cause condensation and precipitation. Sometimes there are extremely heavy local showers, often called cloudbursts. Much of the precipitation at the higher elevations, even in the summer months, is in the form of snow. June, July and August are practically the only months in the year when rain falls at or above timber line. Snowfalls are not uncommon down to an elevation of 6,000 feet, even in May.

The rain runs off quickly and may immediately influence the streams. The snow remains until it is melted or evaporates. Its effect is gradual, and may thus last for some time. Most of the winter precipitation in the mountains remains on the ground in the form of snow until spring. A portion, sometimes not inconsiderable, evaporates, especially when the snow is porous or soft. It may then be seen to visibly decrease. Heavy winds which blow the snow about increase this loss. Some of the mountain observers say, "The wind just naturally wears it out."

In the case of land denuded of timber the surface is generally hard, and the water runs off rather than penetrates. In the forest areas the soil is looser, more porous and absorbent, and takes up water freely. In such areas springs, or springy soil, are more common, while they are rarely found in tracts burned over or denuded of timber. It is the water from these springs which maintains the flow of the rivers from September to April. Their decrease is cause for alarm. Within the past few years the Poudre at one time fell to less than forty cubic feet per second. April and May are the months of heaviest rainfall; most of the continued storms occur during these months. Yet, our river records, now carried on for nearly twenty years, show that these rains have comparatively little effect. A rise in the river due to a storm is distinguishable from one due to melting snow, as may be seen from the diagrams. The snows show a daily tide, usually at the same hour. The rises due to storms are irregular in time and character. An unexpected effect is that rains in the mountains usually decrease the amount of water. The cloudiness associated with the storms prevents more thawing than the rain supplies.

If the area covered by snow has been extensive and extends to a relatively low elevation, with the coming of warm weather the snow melts soonest on the low areas. As a rule these are less protected from the rays of the sun. Melting proceeds, even to considerable elevations, in the direct rays of the sun, though freezing may be going on at the same time in the shade, as on the north side of the ridges. A forest cover protects from the direct rays of the sun just as the ridges do.

In the middle of the summer, snow is to be found at moderate elevations only in the forests or under ridges where sheltered from the direct rays of the sun. As melting proceeds the tributaries are swollen, and the main streams increase in volume, their maximum being reached long before the greatest heat of summer. Though the melting is faster, the snow areas are so much less that the aggregate is reduced, hence, the stream decreases.

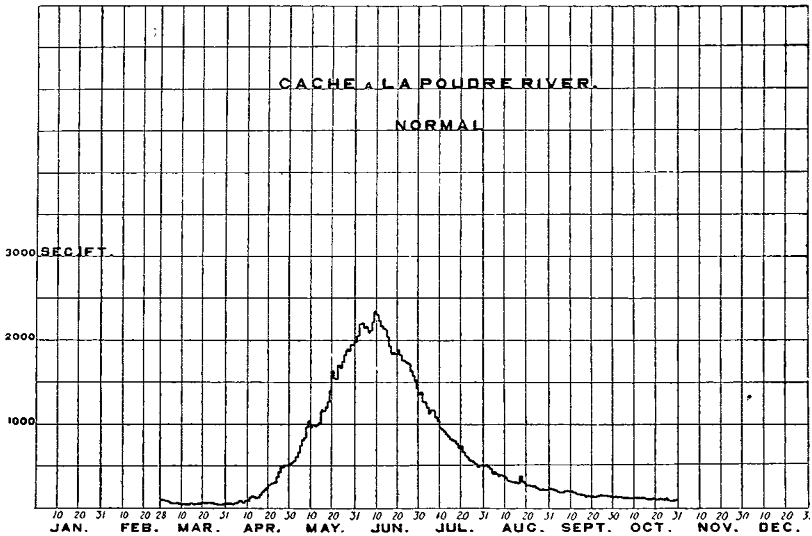

Figure 1.

A typical stream is shown in Fig. 1. This represents the flow of the Cache a la Poudre, on which a longer series of records are available than on any other of the Western streams. The diagram is from nearly twenty years' record of automatic instruments.

The stream is low in fall and winter, when the supply is largely from springs. It rises in April with the rains or melting snows, and more rapidly as the sun and increasing temperature acts on the snow fields.

The rate of rise depends on the area which is covered with snow; on the temperature of night and day; on the dryness of the air, as affecting evaporation; the area of the forest! and the character of the snow, whether it be new and soft or old and hard.

DAILY EFFECT OF THE SUN ON THE MELTING.

A daily rise and fall takes place and is more marked as the river rises. This is shown by the various diagrams. Fig. 2 is a fac-simile of the diagram taken from the instrument during the week from June

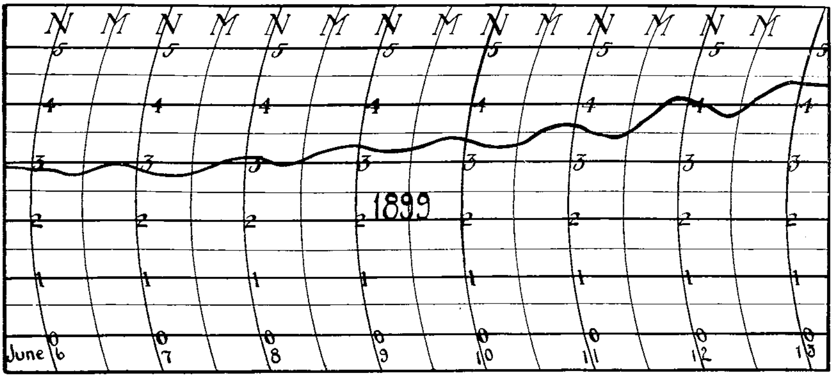

Figure 2.

6-13, 1899. The days are shown at the bottom of the diagram, the gage depths at the left. "N" indicates the noon hour, "M" midnight. The crests of the rises are seen to be twenty-four hours apart. The high water occurs from 4 to 6 a. m. at the point where our instrument is placed, and the low water about 8 p. m. This hour depends on the distance to the snow fields. An examination shows that the extreme fluctuation on June 20-21 was nearly a foot, less on the other days.

When we consider the quantity of water, instead of the depths, this fluctuation appears of more importance. Fig. 4 represents the quantity of water for the same week as shown in Fig. 2. The scale at the left gives the quantities in cubic feet per second. While on the evening of June 20 there was less than 3,000 cubic feet per second, before morning it had become 4,700 cubic feet, falling back to about 3,300 cubic feet during the day, and rising again to 3,900 feet during the night. This diagram is typical of the fluctuation in sunny weather during high water. The change is clearly connected with the diurnal effect of the sun. It is seen in the other diagrams, but almost disappears in cloudy weather.

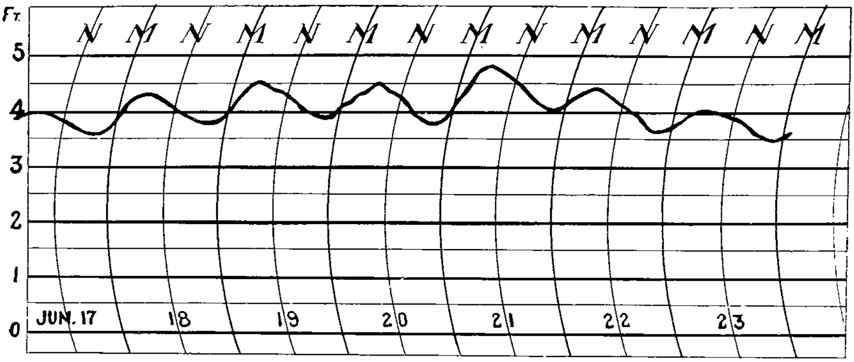

Figure 3.

While the temperature has a marked influence in determining the general stage of the river, the direct action of the sun as shown by the diagrams is still more marked, as it causes these fluctuations. Anything

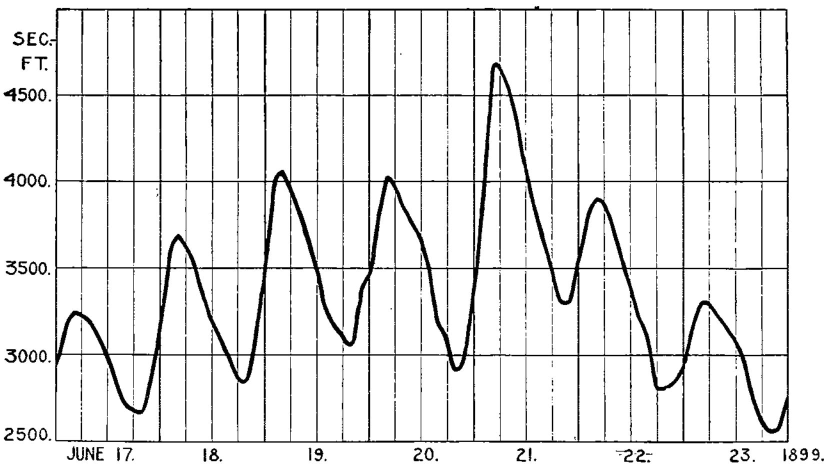

Figure 4.

which serves as a protection from the sun, whether forests, ridges, boulders or clouds, lessens the melting and tends to decrease these tides. This explains the paradoxical fact that a general rain in the mountains often lessens the amount of water in the river.

This effect is illustrated by Fig. 5, which shows the record of a rainy week in 1898. On June 1 the diurnal fluctuation was slight, on

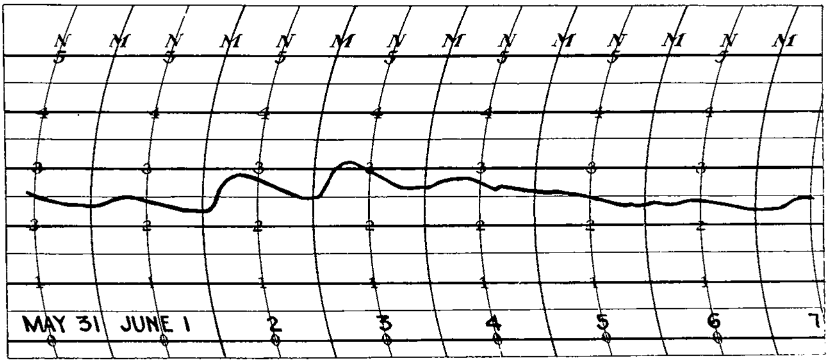

Figure 5.

June 2 it was more marked, and still more so on June 3. For the rest of the week it was scarcely noticeable. The days of June 1 and 2 were sunny, the two following days were rainy, and the rest of the week cloudy. On the night of June 3-4, 1.12 inches of rain fell at the Station, an unusually heavy rainfall, yet the river was lower after this rain than before. The clouds protected the snow from the sun, and this was of more effect than the exceptional rain.

Another record illustrating the effect of a general cloudiness, is for the last week in May, 1897, shown in Fig. 6. The flow for this week was

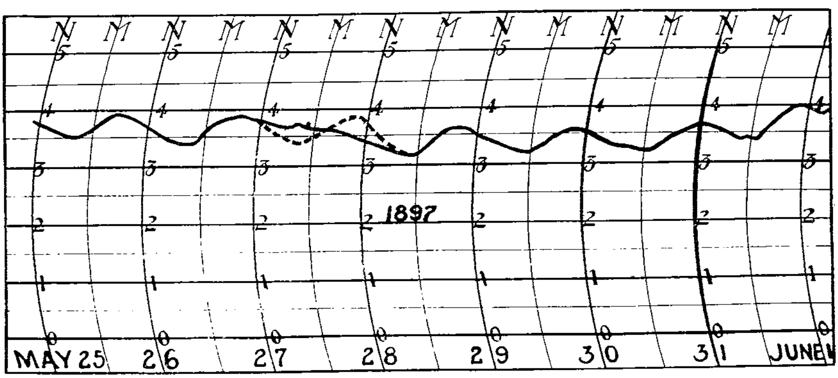

Figure 6.

normal, except on the 28th, when the river lacked the fluctuation evident on the other days. This was due to the character of June 27. It was cloudy and rainy all day at Fort Collins, and also over the whole watershed. The precipitation at the Station amounted to .28 in. There were hard showers near the river, as shown by the slight rise on the afternoon of the 27th. At Westlake, at an elevation of about 8,500 feet and about the middle of the watershed, the precipitation was .80 in. Notwithstanding this heavy rainfall the river shows a steady decrease. The dotted line shows the probable course of the fluctuation, as judged from the records of co-operating observers, had there been no storm and the weather remained clear.

The different effect of a local shower on the river is shown in Fig. 7. Two local storms are in evidence on this record; one on the afternoon of May 18, and the other beginning to show on the afternoon of May 20, with a marked rise during the night.

The storm of May 18 was a sudden violent shower over a small area. As it was near the river, the effect was very marked. The rain-gauge at the Station recorded only .03 in. A shower of .20 in. on May 19 does not show; but there was a storm on the night of the 19th and extending throughout much of the forenoon of the 20th, amounting to 1.28 inches. This was heavy in the mountains also, especially at the lower elevations. The effect is seen in that the river continued to rise on the morning of the 20th, instead of falling. The sudden rise about midnight was due to the access of the flood from one of the important tributaries.

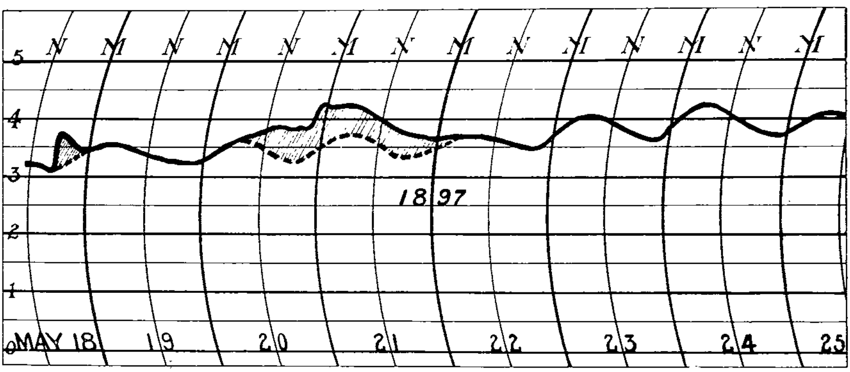

Figure 7.

The dotted line shows the probable fluctuation of the stream if there had been no storms. Neither of the storms extended to the higher elevations and did not cause general cloudiness, and the general course of the river was but little affected.

As snow is most evident on the high peaks, undue importance is attached to high elevations. The run-off from the forest fringes below timber line is of far more importance. The precipitation at the high elevations is not much, if any, more than at lower elevations. The rainfall on Pike's Peak, standing as it does on the edge of the Plains, cannot be considered representative of the other high elevations, and is undoubtedly much greater than that on other peaks equally as high. Even if a great amount of precipitation falls on the top, it is confined to a small area of relativey little importance. Thus, for instance, I have had occasion to examine the watershed tributary to the Rio Grande. While this has an area of 4,611 square miles above 8,000 feet elevation, there is less than 200 square miles of it above 12,000 feet, although this watershed has a large number of the highest peaks in the State.

In this case, over 90 per cent of the watershed is below timber line and above 8,000 feet.

That the forests in the mountains increase the amount of precipitation does not seem probable, whatever their effect when on the plains or lands of low elevation may be. The precipitation in the mountains is mostly due to the cooling from expansion, caused by the air being forced upward by the mountains. The effect of the forests would be so small compared with the mountains that it does not seem possible that they would increase the amount of rainfall. It, however, is not impossible that in the maintenance of moist conditions, influence on the currents of air, and the protection of slopes from the burning rays of the sun, there may be an effect even on the amount and distribution of the rainfall. Nevertheless, they influence the river floods, and protect the snows from melting and the action of the winds. As a protection from floods, they form a feature which the agricultural interests of the State should jealously protect.

CONCLUSIONS.

1. The mountain streams in the early irrigation season are largely supplied by melting snow.

2. There is a marked diurnal fluctuation, greater with high water than with low, due to the daily variation in the rate of melting.

3. The stream at high water may be one-half greater than at low water on the same day.

4. Cloudy weather in the mountains, protecting the snow from the radiation of the sun, causes the fluctuation to disappear and the flow to decrease.

5. This decrease is so great that the cloudiness associated with continued rain usually more than counterbalances the gain from the rain.

6. The loss of snow by evaporation is considerable, especially when exposed to winds.

7. Snow remains in the timber and in protected spots much longer than where exposed.

8. This is due not so much to drifting as to shelter from the radiation afforded by the forest cover.

9. Hence, the greater amount of forest cover the less violent the daily fluctuation, the more uniform the flow throughout the day and throughout the season, and the later the stream maintains its flow.

10. The loss of the forest cover means more violent fluctuation during the day, greater difficulty in regulating the headgates and keeping a uniform flow in ditches and hence an additional difficulty in the economic distribution of water. Also the water runs off sooner, hence the streams drop earlier in the summer and on account of the lessening of the springs, the smaller is the [redacted] flow. winter

11. The preservation of the forest is an absolute necessity for the interest of irrigated agriculture.

PLATES.

PLATE 1.—11:30 a. m., June 21, 1899. Elevation about 9,600 feet. Looking southwest into dead timber. Medicine Bow Range in the distance.

PLATE 2.—11:40 a. m., June 21, 1899. Looking northeast into open white pine timber. Ground sloping gently to the northwest. Snow drifts from three to five feet deep.

PLATE 3.—3 p. m., June 21, 1899. Looking east. Plates 9, 10, 11 and 12 were taken near here. Mr. Zimmerman is shown on the drift.

PLATE 4.—11:00 a. m., June 21, 1899. Looking northwest, showing Mr. Zimmerman behind drift. Slopes to the northwest. Drifts hard. Elevation about 9,600 feet. Open white pine timber. Nos. 5 and 6 taken from this point.

PLATE 5.—11:00 a. m., June 21, 1899. Looking north from same point as No. 4.

PLATE 6.—11:20 a. m., June 21, 1899. Looking southwest into dead timber.

PLATE 7.—10:30 a. m., June 21, 1899. Snow in the open white pine timber. Slopes to the north. Nearest drift, 60 feet long, 48 feet deep, 15 feet wide. Snow granulated. Elevation about 9,600 feet. Looking southwest.

PLATE 8.—4:05 p. m., June 19, 1899. Near No. 13. Snowdrift in the distant green timber.

PLATE 9.—12 m., June 21, 1899. Looking southwest. Bare slope. Elevation about 9,600 feet.

PLATE 10.—1:30 p. m., June 21, 1899. Drift 10 feet deep in green timber. Usually no snow here after June 1st. About 200 yards in timber from points where Plates 1 and 2 were taken.

PLATE 11.—2:45 p. m., June 21, 1899. Snow drift in green timber. From same point as Plate 12. Looking east. Ground slopes to east. Drifts about 12 feet deep, solid. Same drifts as in plates. Elevation about 9,000 feet. Four miles back of Zimmerman's.

PLATE 12.—2:40 p. m., June 21, 1899. From the same place as Plate 11. Looking southwest through dead timber. Mount Cameron in the distance.

PLATE 13.—8:50 a. m., June 24, 1899. Looking north. Elevation about 10,000 feet. Headwaters of the Laramie River. Ground slopes to the south.

PLATE 14.—9:45 a. m., June 24, 1899. Looking southwest. Near No. 13. Spruce and balsam.

PLATES 15, 16, 17 and 18.—June 24, 1899. From same point. Elevation about 9,800 feet. These views overlap, and may unite into one view. **No. 15,** 9:45 a. m. In dead timber, looking west. On south slope. **No. 16,** 10 a. m. Looking northwest into green timber. **No. 17,** 10:15 a. m. Looking north at south slope, showing snow in green timber. **No. 18.** 10:15 a. m. Looking northeast. Snow in green timber, bare ground in dead timber. Showing edge of snow between dead and green timber.

PLATE 1. From the same spot as Plate 2. Same date. Looking northwest.

PLATE 2. Looking northeast into green timber. June 21, 1899.

PLATE 3. Snow drift. June 21, 1899.

PLATE 4. From same point as Plates 5 and 6.

PLATE 5. On border between dead and green timber.

PLATE 6. Looking into dead timber.

PLATE 7. Snow-drifts in pine timber.

PLATE 8. Distant snow drifts.

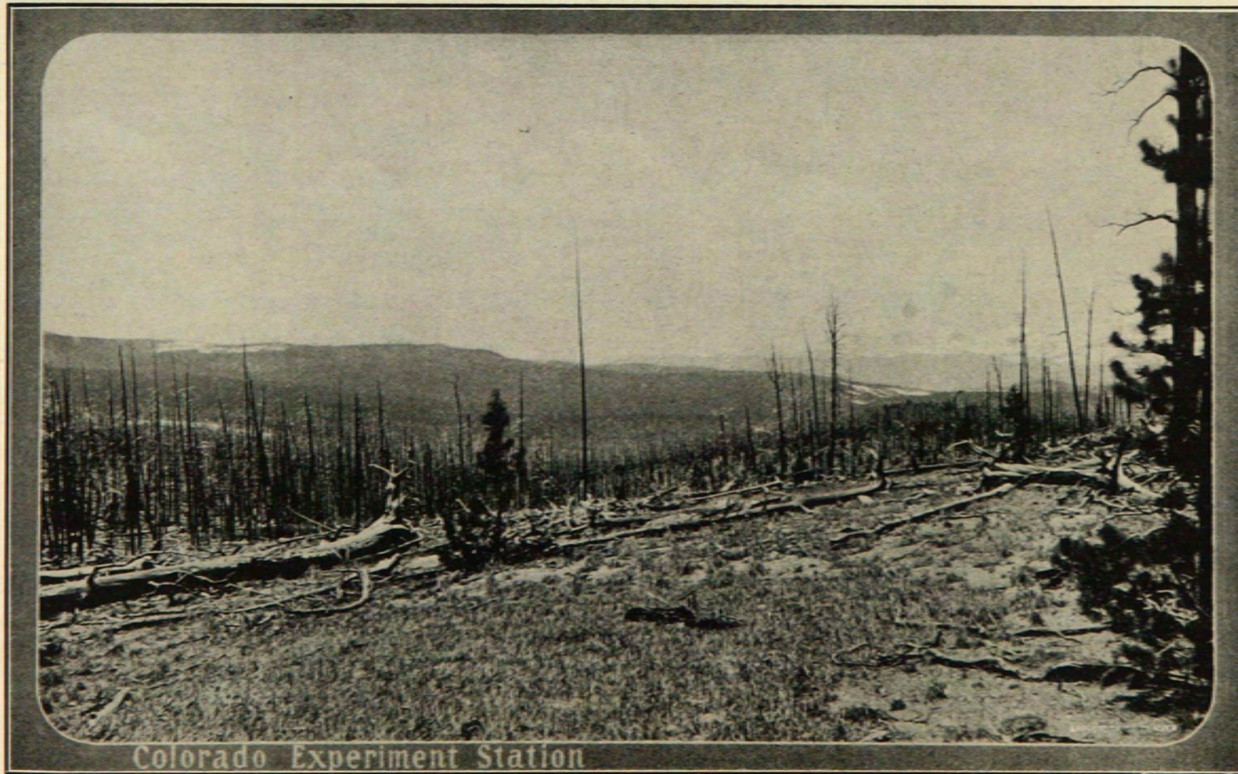

PLATE 9. Looking southwest. Bare slopes.

PLATE 10. Drift in green timber.

PLATE 11. Looking east from same place as Plate 10.

PLATE 12. Looking southwest into dead timber.

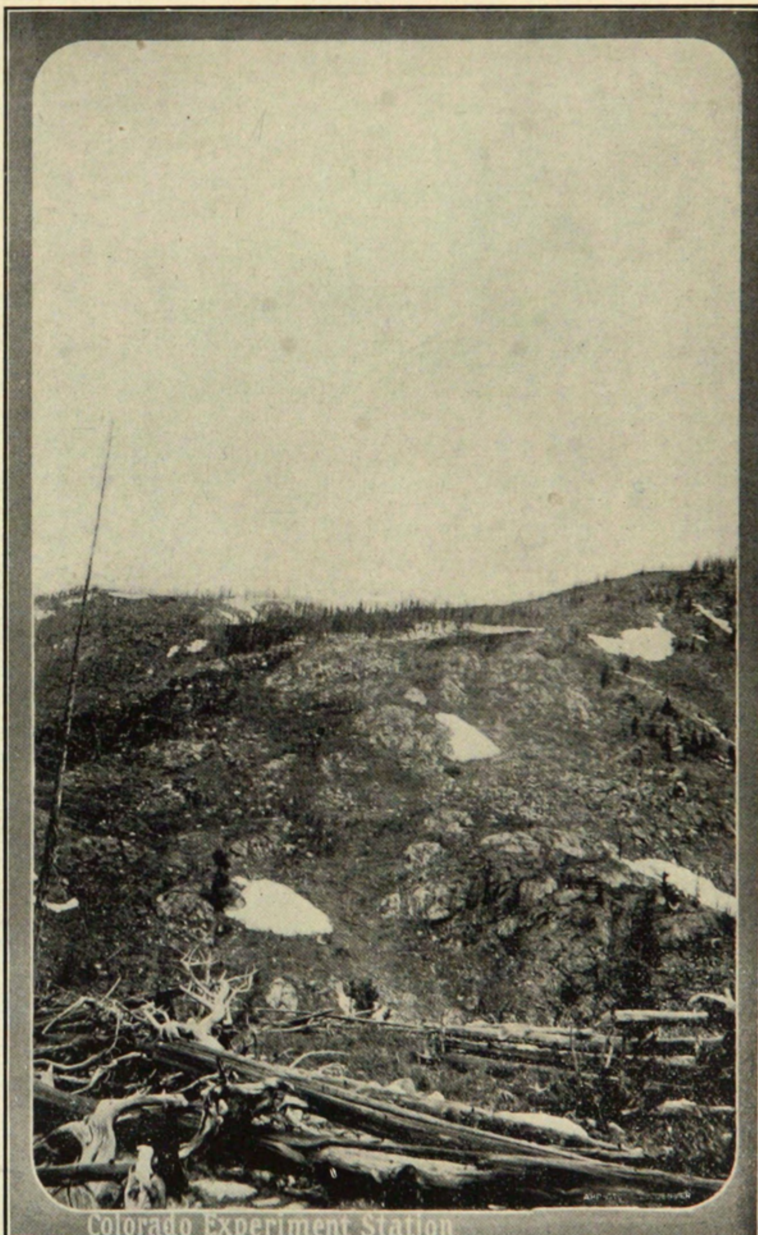

PLATE 13. Snow in sheltered spots.

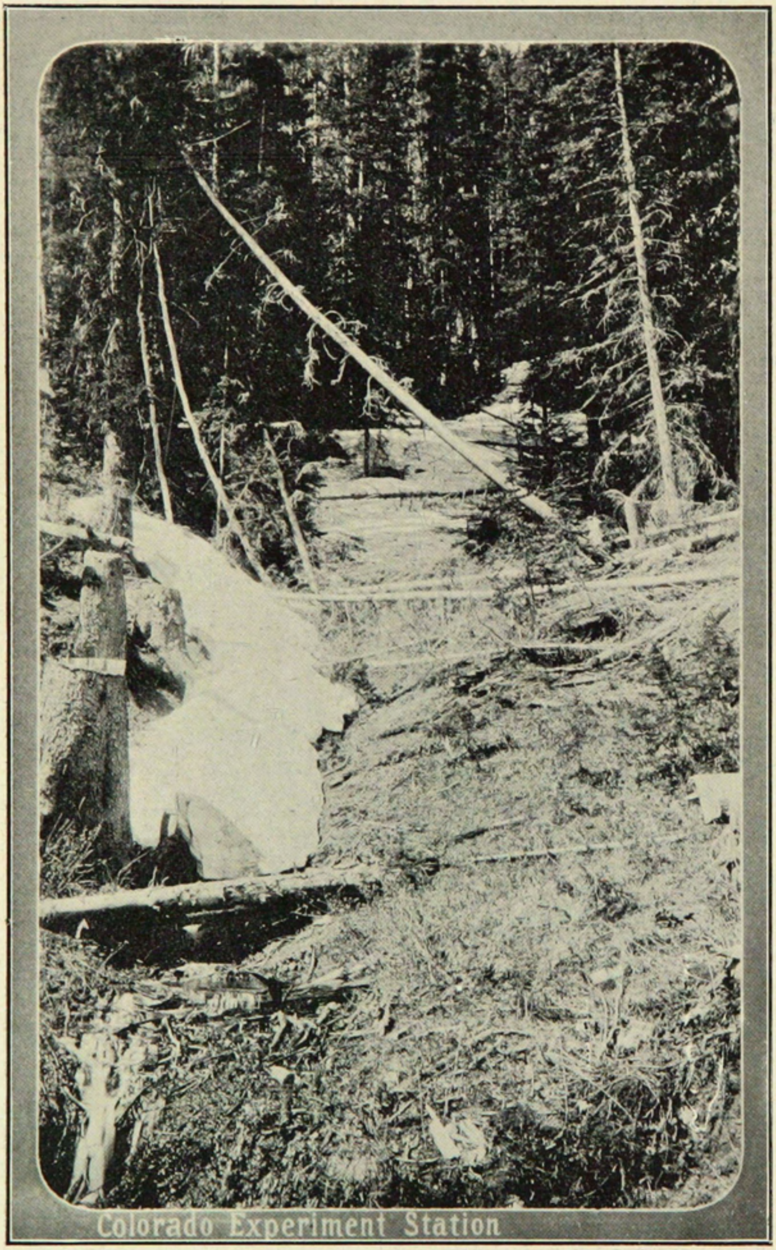

PLATE 14. **Snow in sheltered ravine.**

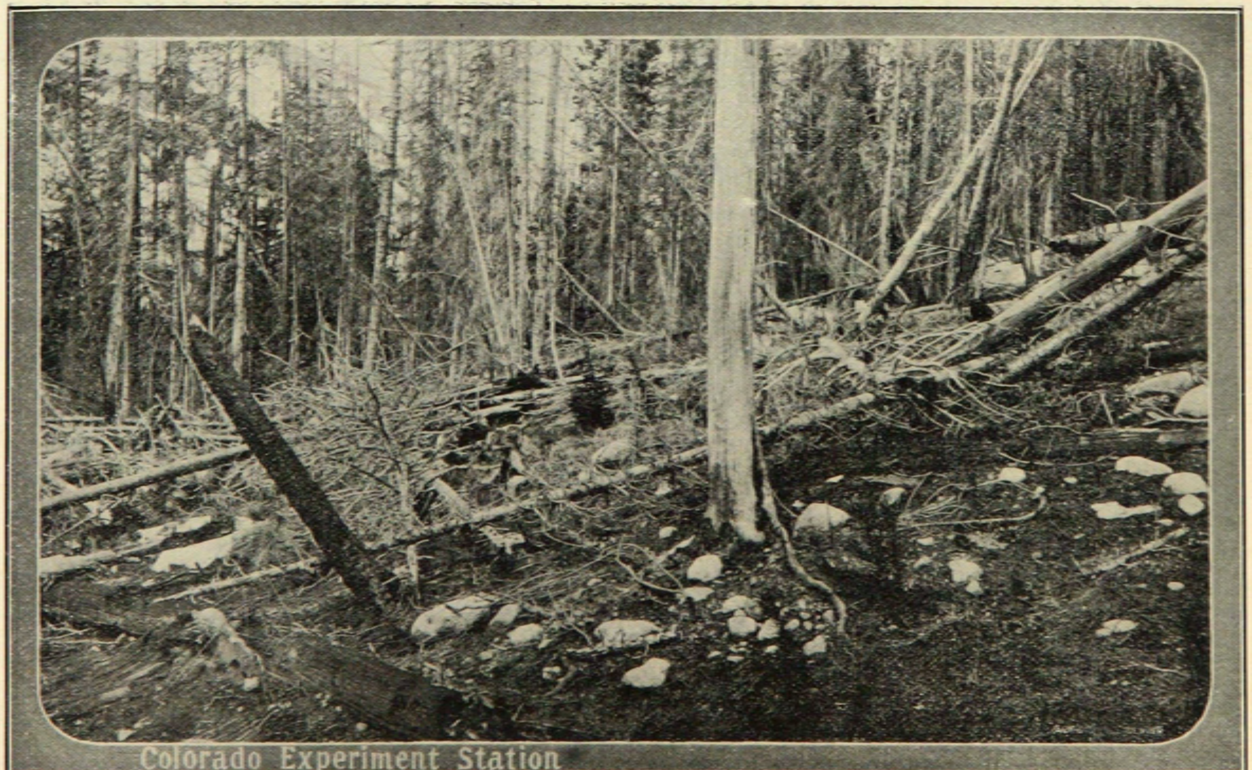

PLATE 15. Plates 16, 17 and 18 from same point. Looking west.

PLATE 16. Looking northwest.

PLATE 17. Snow in green timber looking north.

PLATE 18. Looking northeast.

PUBLISHERS PRESS ROOM CO.
1441 Curtis Street,
Denver, Colo.