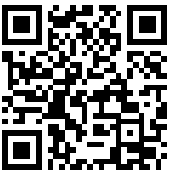

E. D. Orth.

AUTHOR'S EDITION.

THE ROCKY MOUNTAIN LOCUST.

PERMANENT COURSES FOR THE GOVERNMENT TO ADOPT TO LESSEN OR AVERT LOCUST INJURY.

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[Extracted from the Second Report of the United States Entomological Commission.]

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CHAPTER XIV.

COURSES THAT MAY BE ADOPTED BY THE GENERAL GOVERNMENT TO LESSEN LOCUST INJURY.

The First Report of the Commission was the result of labors directed against the unfledged locusts as they hatch out in the more fertile portions of the Mississippi Valley and ravage the crops in what we have designated as the Temporary region. An equally important—nay, more important—problem left for solution was how best to destroy the insect in its native or permanent breeding-grounds, or how to prevent the destructive migrations of the winged insects from the Permanent region to the more thickly settled and fertile country. As intimated two years ago, the solution of this problem, if at all possible, would require several years of investigation. The writer has been deeply impressed with the importance of concentrating all efforts of the Commission to the obtaining of facts that bear directly on this important question. Of the different means that have been suggested we mentioned six more particularly, in our first report, and discussed some of them hopefully, as follows:

"1. The protection and encouragement to the increase of the native locust-feeding birds. 2. The introduction of foreign locust-feeding birds. 3. Inducements offered to the Indians to collect and destroy the eggs and young. 4. Destroying the eggs or young by making the greatest possible use by artificial means of the natural water-supply. 5. Burning the young in spring. 6. Diverting winged swarms by means of smoke.

"While every one of these suggestions might be carried out in exceptional cases to advantage, and while it is the intention of the Commission to endeavor to acclimate certain foreign locust-feeding birds,[339] yet the

[339] In the summer of 1878, with the coöperation of Mr. Montague R. Leverson, of Leverson Ranch, Douglas County, Colorado, we imported two dozen English rooks with a view of sending them out to be acclimated in Colorado and in the belief that this bird would prove one of the most useful to acclimate there. The birds were badly handled on the voyage and detained in the custom-house in New York, and we ar-

last two methods are the only ones which at present we have any faith in as capable of sufficiently general application or as resulting in general good. The first question to consider is whether the insects can be prevented from migrating from their permanent breeding-grounds, and—considering excessive multiplication the immediate cause of migration—this virtually means whether they can be prevented from becoming excessively multiplied in such breeding-grounds. At first view it would seem hopeless to attempt anything of the sort, and a year ago we had such a vague and imperfect knowledge of these permanent breeding-grounds that any proposition looking to wholesale destruction of the insects in them would have appeared Utopian. But we have learned enough of the laws governing the movements of the species and of the country designated as the Permanent region to give us faith, not only in the possibility of thus keeping the species in check east of the Rocky Mountains, but in its feasibility.

"There is a popular notion that this pest breeds in and comes from sandy, desert countries. It is a popular error. The insect cannot live on sand, nor does it willingly oviposit in a loose, sandy soil. It does not thrive on cacti and sage-brush. It flourishes most on land clothed with grass, in which, when young, it can huddle and shelter. It can multiply prodigiously on those plains only that offer a tolerably rich vegetation—not rank and humid, as in much of the prairie of Illinois, Missouri, &c., but short and dry—such as is found over much of the prairies and plains of the Northwest. Now, the destruction of the eggs, which is so practicable and effectual in settled and cultivated sections, is out of the question in those vast unsettled prairies; but the destruction of the young locusts is possible. Those immense prairies are not only susceptible of easy burning, but it is difficult to prevent the fire from sweeping over them. Some system of preventing the extensive prairie-fires in autumn that are common in that country, and then subsequently firing the prairie in the spring, after the bulk of the young hatch, and before the new grass gets too rank, would be of untold value if it could be adopted. The more we study the question, and the more we learn of those breeding-grounds, the more feasible the plan grows in our minds. The Dominion Government has, fortunately, a well-organized mounted police force, which constantly patrols through the very regions where the insects breed north of our line. This force is intended to see that the peace is kept, to watch the Indians, to enforce the laws, and perform other police duties. It could be utilized, without impairing its efficiency as a police force, in the work we have indicated, or it might be augmented for that same work. We have conversed with the ministers of Agriculture and of the Interior, and with Governor

ranged with the present Commissioner of Agriculture to have them taken care of at the Department grounds before shipping them West. Those that had not died on the way arrived in such feeble condition, however, that they soon perished, with the exception of one which is probably yet living in the neighborhood of Washington.

Morris, on the subject, and they see nothing impracticable in the plan. Indeed, it was suggested by Mr. Dawson in his first report on the subject of locust ravages in British America, and by Mr. Riley in his eighth Missouri report, for 1875 (p. 132). We have, on this side of the boundary line, a number of signal stations and military posts in the country where the insect breeds. We would have our own military force co-operate with the Dominion police force as a locust vigilance committee. Under the intelligent guidance and direction of some special commissioner or commission, we would have that whole country systematically studied every year by such a force with reference to the abundance or scarcity of the locusts. We would have such a vigilance force, by a proper system of fire-guards and surveillance, prevent the fall fires in sections where the insects or their eggs were known to abound, in order to burn them at the proper time the following spring.

"This would be a stupendous work, and perhaps too expensive ever to be carried out, did the insects breed over the whole of the region we have designated as the Permanent region; but, fortunately, the breeding-grounds are in limited areas in this region, comprising the richer valleys and plateaux and strips along water-courses. It is for the Commission to accurately map out in detail these areas, and to estimate with what force and at what expense to the two governments the work can be performed. We have no hope nor idea that the pest can ever by human means be exterminated from that vast region, but do believe that it may be so kept in check that it will not migrate. The constant expense will be limited to the employment of the necessary force, and only at intervals when danger threatens will it be necessary to go to the extra and exceptional expense of destroying the insects. Again, as may be gathered from Chapters VII and XV, there is a connection between locust-increase and seasons of drought, and we may take advantage of this knowledge by making especial effort whenever the character of the seasons indicates danger.

"The next question to consider is, whether the farmer can be protected from the invading swarms, in case the above-mentioned plans should fail and the insects had become numerous. We think that this is also, to a large extent, possible with the proper system and organization. We would, in such an event, have this same corps of observers watch carefully the development and movements of the locusts and forewarn the farmers of the country of threatened danger. There is no reason why the agricultural community should not be informed the previous autumn as to the extent to which eggs have been laid, and as to the particular locations where laid; or why, the following spring, they should not be informed of the prospects, so as to plant accordingly, as recommended in Chapter XIII, *i. e.*, put in a larger area of small grain that will be harvested before the winged swarms appear, and plant such crops as are best protected. Then, as the insects were commencing to migrate, their movements should be communicated to the people through

the Signal Bureau. The information should be as minute, complete, and prompt as possible. These movements may be likened to those of a storm, and the people should receive in advance the danger signal, that they might guard against calamity. The "locust probabilities" are of far more importance than the weather probabilities to the people of the West, and the idea of having them telegraphed over the country does not appear half as chimerical to us now as that of having the weather foreshadowed did a few years ago.

"In this way the farmers could be fully forewarned of approaching danger. We would, in this connection, have the western farmers adopt some general plan of defense against possible invasion. The straw that is now allowed to rot in unsightly masses as it comes from the thrasher, and which encumbers the ground unless burned, should be utilized. Let it be stacked in small pyramids at every field-corner, and there let it remain until the locusts are descending upon the country. Then let the farmers in a township or a county or in larger areas simultaneously fire these pyramids, using whatever else is at hand to slacken combustion and increase the smoke, and the combined fumigation would partially or entirely drive the insects away, according as the swarm was extended or not.

"In short, we believe, first, that by proper co-operation on the part of the two governments interested, the excessive multiplication of this destructive insect may be measurably prevented in its natural breeding-grounds, and that the few thousand dollars that would be necessary to put into operation intelligent co-perative plans are most trifling in view of the vast interests at stake. With an efficient and properly organized Department of Agriculture, liberally supported by Congress; with the aid of the War Department, the Signal Bureau, the Post-Office Department, and the Indian Bureau, the plan could be perfected and carried out at a minimum expense. There is no reason why every signal officer, every postmaster, every mail-carrier, every Indian agent, and every other government employé in the Permanent region should not be ordered to do service of this kind, and made, under the direction of an intelligent head, a medium through which to gather the desired information. We believe, secondly, that where the multiplication of the insect cannot be prevented in its natural breeding-grounds, our farmers in the more thickly-settled sections may, by the use of smoke, measurably turn the course of the invading swarms and protect their crops—obliging the insects to resort to uncultivated areas.

"Did the injury continue for another three or four years as it has for the past four; were the western farmers to suffer a few more annual losses of $40,000,000, such schemes as we have suggested would soon be carried out. The danger is that during periods of immunity, indifference and forgetfulness intervene until another sweeping disaster takes us by surprise. The other danger is that the majority of our Congressmen and Senators at Washington, representing constituencies

never troubled with this grievous pest, have not, and cannot well have, any just conception of the magnitude of its devastations, and are consequently without due appreciation of the importance of the subject."

It is with a view of ascertaining the feasibility and practicability of the last three methods there referred to that we have endeavored to get more accurate knowledge of the limits and character of the Permanent breeding-grounds, whence the destructive swarms emanate, so as to place facts rather than surmises before our readers. In this attempt we have been made fully aware of the difficulties which the problem presents, and to modify somewhat the views previously expressed; but while the difficulties in some portions of the country are practically insurmountable, yet, for a large portion of the country affected, especially the vast plains and prairie regions between the mountains on the one hand and the Mississippi and North Saskatchewan on the other, it is within man's power largely to avoid in the future the immense losses that have hitherto been sustained. The destruction of the eggs by plowing or harrowing may be advantageously carried on and stimulated by bounties in exceptional cases, especially in the Sub-permanent region, but does not admit of any general carrying out on a large scale; so that we need add nothing further here beyond what has been said on this score in Chapter II (pp. 25, 26, 30), to which the present chapter is largely supplementary.

In what way, then, can the national government help to bring about the desired result? There are, it seems to us, seven ways in which government action is possible, viz: 1. By encouraging settlement; 2. By encouraging the building of railroads; 3. By broad schemes of irrigation; 4. By guarding the present timber and encouraging the planting of forests; 5. By judicious burning; 6. By a permanent system of observations and warnings; 7. By co-operation with the Dominion Government in these various measures.

SURFACE CHARACTERISTICS OF THE PERMANENT REGION AND THE PROPORTION OF LAND IN IT UPON WHICH THE VEGETATION IS SUSCEPTIBLE OF BEING BURNED.

A consideration of the surface characteristics of this Western country, including soil and vegetation, will greatly help to intelligent discussion of either of the above propositions, and particularly of the fourth. To this end we have had prepared, in six separate parts, the large map (I) which indicates, as fully as present knowledge permits, the character of the vegetation in the region in question, and more particularly that which is sufficiently dense and luxuriant to permit of being burned over. The dividing lines between the probable breeding-grounds and the land that is grass-covered, as well as those between this last, the semi-desert and the desert land must needs, in many cases, be more or less arbitrary as they shade into each other, and the map cannot, even in those parts where every mile is familiar to us, be more than approximately correct.

Yet it serves admirably to show the small area over which the locusts really breed in great numbers, compared to the whole extent of the region. We have, also, in studying this question, so as to elaborate the general description given on p. 71, found it convenient to separately consider, 1, the Plains Area east of the Mountains; 2, the Mountain Area; 3, the Plateau Area; 4, the Great Basin Area: and in doing so we have not only been guided by the experience of each of the commissioners, but have drawn from other available sources.

The investigations of the past two years have led to a considerable enlargement of the Permanent region, as we intimated in our first mapping of the region[340] that they might do when Idaho and Montana had been more fully studied. Our former estimate was that the region covered, approximately, 300,000 square miles, whereas, owing to the inclusion of the western border of Dakota and larger portions of Western Wyoming, Utah, and Southern Colorado, as indicated in the map accompanying this report, it will probably embrace more nearly 400,000 square miles.

We are particularly under obligations to Mr. Henry Gannett, E. M., who, as topographer for many years of Hayden's Geological and Geographical Survey of the Territories, has obtained very thorough personal acquaintance with the country under consideration. He has kindly aided us in every way in his power, and furnished most of the data relative to the mountain and plateau areas.

The Plains Area East of the Mountains.

The vegetation of this area may be classified as follows:

1. The grasses which, though of many distinct species, are, on the uplands characterized by growing in bunches and never forming a sod, whence the general name *bunch grass*, by which they are popularly known. The commonest of these grasses on the plains is the Buffalo grass (*Buchloe dactyloides*). In the most southern of the Territories several species, known commonly as Grama grass, abound; the commonest of these is *Festuca macrostachya;*

2. *Artemisia*, or sage-brush, is perhaps the best known of the products of the West, as it is certainly the most abundant. Of these the species which is the widest spread is *A. tridentata;*

3. The cacti, of which the prickly pear, *Opuntia*, is the most abundant; and

4. Greasewood, a name applied to a variety of desert shrubs, the true greasewood being *Sarcobatus* (?) *vermicularis.*

As may be noticed, these staples of the uncultivated soil are by no means varied, nor are they, with the exception of the grasses, of much economic value.

Let us now take a glance at the general geographic distribution of these staples.

[340] First Report, p. 131.

The Great Plains, extending from the North Saskatchewan to the Mexican boundary, are mainly covered with the various bunch grasses. The luxuriance of the growth differs greatly in different localities, being modified by the general and local climate. In general terms the growth is more luxuriant in the north than in the south, and in the eastern portion than towards the west, although at and near the base of the Rocky Mountains and Black Hills the growth is again quite luxuriant, owing to the increased moisture of climate produced by the proximity to the mountains.

Here and there, in the more arid localities, which will be defined in some detail farther on, are areas wholly or in part given over to sage, cactus, or the Spanish bayonet (*Yucca angustifolia*).

Passing beyond the wall of the Rocky Mountains one enters still more arid regions where the grasses give way still more to Artemisia, and other members of the arid flora, which, in the great interior basin, between the Rocky Mountains and the Sierra Nevada and Cascade Range, form the primary growths of such of the country as is not utterly sterile.

Everywhere, however, on the mountain slopes the country is better watered than in the valleys, and where not covered by timber the grasses are more luxuriant than below.

The bottom lands of rivers, too, are, for a greater or less breadth, in a measure artificially irrigated, and the grasses are more close, approaching a turf, and often grow much higher. Such areas, however, are comparatively insignificant in extent. Many of these bottom lands, too, are covered with willow and cottonwood trees, to the partial or total exclusion of grasses. In the region of the plains and the great interior valleys, these strips of timber along the streams are practically the only timber.

Greasewood takes the place of Artemisia in many localities, seeming to prefer a heavy alkaline clay soil, while sage grows indifferently on a clayey or sandy soil, but on the latter it grows most freely and luxuriantly.

"Burnable" land (and by this term we mean land susceptible of being burned over cheaply and economically) is *practically identical with grazing land.* Bunch and grama grasses burn with the greatest freedom, the only difficulty being to control the fire and prevent it from doing damage. Most sage-land has more or less grass among the sage. Indeed, grass-land grades into sage barrens by insensible degrees and as the latter are burnable only with difficulty, the line of division between burnable and non-burnable land must in this case be mainly an arbitrary one, drawn according to the judgment of the observer.

A heavy luxuriant growth of sage will burn freely, as travelers in the West have had frequent opportunity of observing, but a low, stunted growth of this plant, which covers great areas of thin, poor soil, can be coaxed into burning only by constant attention, and it would therefore be very expensive to burn over great areas.

Greasewood will not burn freely, owing to its being a sparse growth; and as the Rocky Mountain locust does not frequent the cold, clayey soils which produce this plant, such regions are of no importance in this connection.

Timbered lands are not considered in this connection, as these insects do not breed in a timbered country.

The great area of the plains, stretching eastward in a long inclined plain from the base of the Rocky Mountains, is therefore mainly covered with grasses, which are mostly low, seldom forming a sward but growing in bunches or tufts.

In the British Possessions the area of the plains, or level, untimbered regions, is divided by Mr. Dawson, the Canadian geologist, into three "prairie levels" or steppes—steppes with very slight rise and long trend. The first of these includes the region of the Lakes Winnipeg, Manitoba, Winnepegosis, &c. It is heavily timbered, except near its western border. Its mean elevation is not far from 1,000 feet. Rising from this, westward, in bluffs two or three hundred feet in height, is the eastern escarpment of the second prairie level, of which the Coteau des Prairies, in Minnesota, is the southern extension. This is tolerably fertile, well grassed, with timber only in the bottom lands of the streams and on knolls and the faces of bluffs. Its elevation is from 1,200 to 1,500 feet above the sea, gradually rising westward. The third prairie level is what corresponds, in the United States, to the plains proper and the Coteau du Missouri. It rises from the last in ill-defined bluffs, of small height. From the edge it gradually increases in height westward until, at the base of the Rocky Mountains, it is 4,000 to 5,000 feet above the sea. On this level the grass is shorter, less luxuriant, and in some places, especially near the boundary, shows the effect of a climate decidedly arid by the presence of sage and cacti. Timber is distributed very much as on the second level, but is decidedly more scarce.

As we proceed northward over the two upper prairie levels in the country between the forks of the Saskatchewan, the climate becomes moister with the increasing cold, and the vegetation approaches more and more the nature of that on the true prairies of the Mississippi Valley; and north of an undulating line which follows approximately the course of the 52d parallel, patches and belts of timber begin to diversify the surface, alternating with the rich grasses. The change from prairie to forest goes on gradually over a belt 50 to 75 miles in breadth, and the North Saskatchewan is reached before the forest has asserted sole proprietorship. South of Belly River, more arid conditions manifest themselves. At the base of the Rocky Mountains, and indeed for a hundred miles eastward, and about the Judith and Big Horn Ranges, the influence of the mountains in inducing a moister climate is plain; the grass is tolerably luxuriant everywhere, and especially so at the base of these ranges, gradually shading off in luxuriance with the distance from them.

Near the meridian of 117°, and just north of Milk River, begins an area of sparse vegetation, which extends southeast across Milk, Missouri, Musselshell, and Yellowstone Rivers, and terminates in the western part of Dakota, north of the Black Hills. Its boundaries are very ill-defined, as it grades off on all sides into the ordinary grass land of the prairies. Where it crosses the boundary line it is not far from 75 miles in width. Its western limit crosses the Missouri not many miles below Fort Benton, runs around the Judith Mountains at a distance from them of not far from 10 miles, crosses the Musselshell in longitude 110°, and thence bears generally southeast, keeping at a distance of a few miles from the eastern base of the Yellowstone and Big Horn Ranges. Its greatest southerly extension is reached between the Big Horn Range and the Black Hills. Thence passing northeast by the Black Hills, its line, now its eastern boundary, runs north in the longitude of the eastern base of the Black Hills, embracing the Bad Lands of the Little Missouri, the Powder, and Lower Yellowstone Rivers. Crossing the latter stream, it runs generally northwest to the point first mentioned. North of the Yellowstone, this region is characterized mainly by the sparsity of all vegetable growth, the grass is scanty and short, and there is much cactus. South of the Yellowstone, on the lower waters of that stream, the Powder, and Little Missouri, are Bad Lands, where the surface is much broken by minor typographical features, caused by the rapid erosion of soft strata. There is but little vegetation, with great areas of bare, powdery, clay soil. Higher up, on and between these streams, the prevalent growth is sage.

What has been said regarding the vegetation of the second and third prairie levels is equally true concerning the coteaus of the Minnesota and Dakota. While forming parts of these prairie levels, they are in fact plateaus of no great elevation, being 1,500 to 2,000 feet high, and well marked by bluffs everywhere, except on the north. They have a rough, undulating surface, gravelly or rocky soil, containing many "sinks," but are not well watered. The luxuriance of the grasses varies very much with the locality, but is nowhere too sparse to burn with the utmost freedom.

Within the United States the general character of the grasses may be thus briefly expressed:

In Central Nebraska and Kansas, Western Indian Territory, and Central Texas, which is the belt lying just west of the western border of timber, the grasses are high and luxuriant, as should be expected, on account of the comparative moisture of the climate. Westward, as the aridity becomes greater, the grasses become shorter and sparser, and this progression continues until we near the Rocky Mountains, where their influence in rendering the climate moister is shown in the increased luxuriance of the grasses.

In all this wide expanse of plains south of the Black Hills the area which cannot be easily burned over is very small. The Bad Lands be-

tween the Niobrara and White Rivers, and the sand hills on the latter stream, form the only exceptions worthy of note, and indeed it is doubtful whether they should be excepted. The Llano Estacado is mainly covered with fine grass, while Jornada del Muerto, of New Mexico, derives its name, not from having the characteristics of a desert, but solely from the dearth of water.

The Black Hills are an isolated group of mountains, some 75 miles in length by 50 in breadth, rising to a height of 6,000 to 7,000 feet above the sea, and about 3,000 feet above the surrounding level. They are heavily timbered throughout, while about their base the grasses are everywhere luxuriant.

The Mountain Area.

With regard to the Rocky Mountain region of British America, it may be briefly dismissed, as little is known about it in detail. It is essentially a heavily timbered region. It is made up of a number of ranges trending parallel to one another and separated by narrow valleys. It is a region of heavy rainfall and slight evaporation; and not only the mountains but the valleys also are covered with forests.

Within the Western United States the presence or absence, and even the comparative density and the prevalent species, of the forests may be predicted with a reasonable degree of certainty and detail from the latitude and elevation, *i. e.*, from the same elements as there determine the degree of moisture of the climate. Excepting in the northern part of Idaho, Washington, Montana, and Wyoming, the general level of the country is not sufficiently elevated to cover it with forests, and consequently they are, except in the localities summarized above, confined to mountain ranges and high plateaus. In southern latitudes, even, many ranges of considerable altitude are not sufficiently high to reach the lower level of timber, as in the case of the majority of the ranges in Nevada, Arizona, and Southern California.

Occupying the next zone below the forests, we find the grasses. They are found on the foothills of the mountains and the margins of the valleys, and, in cases where the elevation and latitude are sufficiently high to insure moisture enough, covering the valleys. In other cases a zone of sage succeeds, the two growths grading into one another, and this in turn in the most arid localities, as in the deserts of Utah, Nevada, and Southern California, is succeeded by scanty growth of cacti, yucca, and by naked soil without vegetation. This succession, being a direct result of the conditions of aridity, can be premised regarding a certain region with considerable certainty.

The more northern section of the Rocky Mountains in the United States, including the mountain region of Montana, Idaho, and Wyoming, is characterized, in the northern part, by a tolerably great precipitation, allowing a growth of forests almost as great as in the British Possessions. The whole of Kootenai County, Idaho, is covered by

forests, extending southward, over the Bitterroot, the Cœur d'Alène, and Salmon Ranges, as far south as the Snake River Plains.

The Missouri, which in Northern Montana forms the front rank of the Rockies, is covered with timber. The valley of Flathead Lake, lying at its western base, contains but small patches of open grassy country. The valleys of the Deer Lodge, Bitterroot, and Hell Gate Rivers are all open and grassy. So with the valley of the Jefferson and its branches, the Madison and the Gallatin. These valleys, while not sufficiently moist for the growth of timber, are not too arid for grasses.

The Judith Mountains, the Little Rocky Mountains, and other minor groups scattered about in the more northern plains, are well timbered, the former particularly so.

The Yellowstone River heads in the Yellowstone National Park, whence it flows in a generally northern course, nearly to the latitude 46°, where it turns at right angles to the east, and after a long course eastward and northeastward it joins the Missouri at Fort Buford. Its upper course is walled in on the east by the Yellowstone Range, which separates its drainage. A heavy growth of coniferæ covers the country about the Upper Yellowstone, and that surrounding Yellowstone Lake. On the river, below the foot of the lake, extending from the Mud Geysers nearly to the Falls, a distance of about 10 miles, and westward from the river about the same distance, is an open grassy park country of rolling hills, which was in former times the bed of an arm of the lake. A similar area is found on Pelican Creek, a tributary to Yellowstone Lake, a few miles above its mouth. Aside from these open and burnable areas, very little open country is to be found on this river or its tributaries until we pass the Washburn group of mountains. This group of mountains is in the main part well timbered; the lower northeastern slopes, however, down towards the mouth of Tower Creek, contain little timber, and thenceforward the valley and plateaus of this drainage system are bare of trees and well grassed. Hayden's Meadows, opposite the mouth of the east fork of the Yellowstone, and the plateau above the third cañon of the river on its left-hand side, are nearly bare of trees.

Glancing now at the east fork of this stream, we find its immediate valley as far up as the mouth of Soda Butte Creek, the valley of the latter stream, and of Slough Creek, are all open and covered with grass and sage. The mountains about this stream, too, contain little timber on their lower slopes. The high, broad ridge which separates the east fork from the main river, of which Amethyst Mountain is the culminating point, contains very little timber, but is covered with grasses. The head of the east fork, however, is in the densely timbered region.

The next tributary of the Yellowstone of importance is Gardiner's River. This stream has an open valley extending from its mouth to the forks, a distance of about 6 miles, with an average width of 2 miles. Farther up the stream, on the middle and west forks, is an open valley, 3 miles long by 3 in width. These valleys are covered with the usual mixture of Artemisia and grass.

Below the mouth of Gardiner's River the Yellowstone flows for 8 miles in a sage valley containing enough grass to make it fair grazing land, while grass extends up the slopes of the limiting ranges for nearly 1,000 feet, when it is replaced by timber.

Below this valley follows the second cañon, where the wooded mountain slopes come close down to the river's margin. This is succeeded by a long, broad, grassy valley, extending down to the lower cañon, a distance of 29 miles. This open valley has an average width of 4 to 5 miles. On the east it extends to the base of the Yellowstone Range, and on the west to that of the Gallatin Range, which here separates the Yellowstone from the Gallatin River. This valley contains at present a small ranch population.

Below this fine valley is the short lower cañon, where the river has carved a passage through a bare ridge connecting the limiting ranges. Below this an open, grassy country extends down the river to the bend to the eastward, and up the valley of Shield's River, a large, left-hand branch, nearly to its head.

All the open country on the drainage of the Yellowstone is susceptible of being easily burned over. The soil is almost everywhere more or less gravelly or sandy; nowhere a heavy clay.

The Madison River, like the Yellowstone, heads in the high, heavily-timbered country of the Yellowstone Park, opposite the heads of the Snake. Its drainage area is timbered as far north as the second cañon, below the mouths of its east and south forks. The valleys of these streams, too, are heavily timbered.

From the foot of the second cañon, northward to the lower cañon the Madison Valley consists almost entirely of a succession of terraces of gravelly soil, covered with grass and sage. This valley has a length of 50 miles and an average width of 6 or 7 miles. On either hand is a high range of mountains, timbered almost to their bases. All this valley can easily be burned over.

The lower cañon of the Madison is cut in sparsely timbered hills, below which the river enters the broad expanse known as the Gallatin Valley. This fine large basin, second to none in Montana for agricultural and grazing purposes, save perhaps that of the Bitterroot, has a total length of 32 miles, with a width of 25. It extends southward from the forks of the Missouri, up the Madison and Gallatin Rivers to the north ends of the Gallatin and Madison Ranges, and from the East Gallatin westward beyond the Madison River. The streams which traverse it are the Madison, the Gallatin, and several large branches of the latter, among which are Middle Creek, Bozeman Creek, and the East Gallatin River. These streams have broad bottom-lands, covered with grasses and scattered groves of cottonwoods and willows.

The valley is covered with a fine growth of bunch-grass and some sage. Probably the entire area of the valley can easily be burned over.

The Gallatin and its branches above this valley are in close cañon in a heavily-timbered mountain country.

The Gallatin Valley is partially settled, mainly by an agricultural population. It contains three small towns, Bozeman, Gallatin City, at the Forks of the Missouri, and Hamilton. A large part of the country along the streams is already taken up by ranches. The population of the valley in 1870 is given in the census report as 1,578 souls; and this is probably but slightly changed at present.

Proceeding now to the Jefferson River, the third fork of the Missouri, we find in its drainage area much less timber and more open, grassy country, than in those of the other two forks. The range separating its drainage from that of the Madison is timbered near its crest, but its foot-hills and lower slopes are devoid of trees and well grassed. The valleys of Red Rock Creek and Beaverhead River, are broad, open, and grassy. So with the valley of the Bighole, or Wisdom River, and the hills which form the divide between the latter and the Beaverhead. The mountains which stand at the head of the Beaverhead River, separating this drainage from the Snake River Plains, are well timbered except on the lower foothills.

All the open country on the Jefferson can easily be burned over.

Turning now to the Missouri, we find it flowing with a somewhat sluggish current through a tolerably broad bottom-land of fine grass and groves of cottonwoods. The country on the west, as far as the base of the Missouri Range, is open and grassy, presenting many of the aspects of the plains. This character extends as far north as Helena.

On the east side of the river, the hills and lower mountains are grass-covered, while the higher groups of mountains are clothed with timber. Farther to the eastward, between the Missouri and Yellowstone Rivers, are the Judith, Snow, and Crazy Woman Ranges, all heavily timbered, while the surrounding country is well grassed.

The large valley at the eastern base of the Wind River Range, through which flow Wind River and the Popo-agies, is, near the mountains, well grassed; but as we proceed eastward, away from the mountains, the quality and abundance of its vegetation deteriorate, and on its lower parts it bears all the aspects of a desert.

The Wind River Mountains rise west of this valley and separate it from the Green River Basin. The peaks of this range rise to heights of nearly 14,000 feet. These mountains are heavily timbered from their base to the timber line, which in this range is at an elevation of about 10,000 feet.

The basin of the Bighorn, in most respects, resembles the valley of Wind River. On all sides, near the base of the mountains, is high, luxuriant grass, gradually shading off toward the interior of the basin into sage land and even to desert, in some localities. In the small tributary valleys of several of the western branches of the Bighorn the grass is exceptionally fine, and stock men are beginning to avail themselves of the excellent grazing. On the eastern and northern bases of the Bighorn Range, also, the grass is luxuriant, grading off northward and eastward into poor sage land.

The Bighorn Range, which surrounds the basin of the Bighorn on three sides, is described as being heavily timbered, while the country about its base is exceptionally fine for pasturage purposes, the grasses being very high and luxuriant.

Next we turn to that great area marked on our maps as the "Great American Desert," the Green River Basin. This district, occupying about 11,000 square miles, is limited sharply on the south by the Uinta Mountains. The southern part of the western boundary is ill-defined, being simply a broad, meridional swell in the surface, separating the basin from the valley of the Bear River, a large tributary to Great Salt Lake. Following this divide northward, however, it is seen to develop into high ridges, which, still farther north, have weathered into mountains, the Wyoming Range. The basin extends northward almost to a point, abutting against the Gros Ventre and Wind River Ranges, the latter of which forms a well defined eastern boundary as far as its end near South Pass. Beyond this the eastern boundary is as poorly defined as the opposite western boundary, the land rising by almost imperceptible grades from the basin to the plateaus of the continental watershed, above mentioned.

The northern part of this great area is slightly broken by spurs from the mountains and by fragments of mesas, which have been spared by the erosive agencies. The central and by far the larger part of the basin is unbroken, save by long, gentle undulations, like those of the plains and by the bluffs, which limit the valleys of the few streams which venture into this arid expanse. In its southern portion, on the other hand, the conditions which prevail in the plateau province proper begin to assert themselves. River benches and bluffs develop into cliffs, and valleys change to cañons.

A corresponding gradation in the character of the vegetation is also plainly traceable. While the southern and lower parts of the basin are as arid as almost any part of the North American Continent, the northern and higher parts are well grassed and contain comparatively little sage and no greasewood. The greater part of the basin, however, is of too desert a character to be burned over economically. Those parts where the reverse is the case may be summed up as follows:

The country between the Big Sandy River and the Wind River Mountains; indeed, all that near the southwestern base of this range, the southern part of the basin, extending as far south as Lead Creek, with the western rim as far as Fontenelle Creek, are sufficiently well grassed to burn with tolerable freedom.

The soil of the basin varies extremely in different parts. Near the mountains it is, in all cases, naturally gravelly, coarse or fine according to the distance from their base. At the foot of the Wind River Range, about the debouchure of the several branches of New Fork of the Green, glaciers have in former time brought down immense quantities of boulders, gravel and the like, which now cover great areas. Farther

south, along the courses of the Sandys the soil is of the nature implied by these names, and, farther yet toward the southeast, near the South Pass, and extending thence far to the eastward along the south base of the Sweetwater Mountains is a long range of sand dunes, built up from the accumulations of the prevailing westerly winds.

The broad stretch of country included between the Big Sandy and Green River is mainly sandy, grading, in its southern part into an adhesive, alkaline clay. The soil of the southern part of the basin, *i. e.* that lying south of the latitude of the mouth of the Big Sandy is of the latter character, produced mainly by the disintegration of the Bridger beds. Along Bitter Creek, almost the sole vegetation is greasewood.

West of the Green, in this part of the basin, alkali does not form so large a component of the soils, and while sage is the predominant growth, still grass is found in some localities in sufficient abundance to afford fair pasturage. Passing northward on this side of the river we find the same gradation from a clay to a sandy soil.

The river bottoms of many of the streams contain fine meadow land, which can easily be burned over. Green River, from its head down to Green River City, has a belt of bottom land from one to two miles in width, all well grassed, and containing occasional groups of cottonwoods and willows. Bitter Creek has no bottom land, but flows mainly in an arroyo, cut in the clay soil. The Big Sandy has but little bottom land. From its mouth to that of the Little Sandy it flows in a low cañon, whose walls closely confine the stream. Above this point the bottom lands are narrow, being on an average probably not more than one-fourth of a mile in width.

The various branches of the New Fork of the Green have but narrow strips of bottom land, but they flow through a comparatively well-grassed country.

Nearly all the branches of the Green from the west have broad meadow lands along their courses, in many cases rivalling in width those of the main stream itself. Of these Horse, Marsh, Bitterroot, Piney, and Labarge Creeks have particularly fine bottom lands. The Fontenelle bottoms are narrower, probably averaging not more than a half mile in width, and limited by high bluffs. Slate Creek is an insignificant stream with no flood plain.

The bottom lands of Black's Fork are particularly broad and fine, being fully three miles in average breadth. On its main branch, Ham's Fork, they are nearly as broad, and the same may be said of Henry's Fork, which enters the Green just above its cañon in the Uinta Mountains.

These bottom lands are everywhere well grassed, and in the spring when the grass is dry can easily be burned over.

The rolling plateaus which separate the southern part of the Green River Basin from Bear River are, in this neighborhood, desert-like in character, Artemisia being the principal production. As we recede

northward from the railroad toward the upper waters of Ham's Fork, the face of the country improves, and grass predominates. This continues northward nearly to the head of Ham's Fork, where timber usurps the soil.

Turning now to the headwaters of the Snake River, the southern fork of the Columbia, we find ourselves in a different region. It is in large part mountainous, and with the exception of a few open valleys, most of which are small, it is very heavily timbered. Indeed, this region about the heads of the Snake, the Yellowstone, and Madison Rivers, embraced almost entirely in the Yellowstone Park, is the most densely timbered region in the West, with the exception of Washington Territory and the western part of Oregon.

The Snake heads in a country of high mountains north of the Green River Basin, including the southern part of the Yellowstone Park. Its most northern branch, Lewis's Fork, takes its rise in Shoshone Lake, whence it flows southward. In a few miles it is joined by a large stream from the east. Both these streams flow through a heavily timbered country, where the grassy openings are of a very limited extent.

Below their junction the river keeps its southerly course, through a narrow wooded valley, as far as Jackson's Hole, at the east base of the Teton Range. On either side, the mountains are heavily wooded up to the timber line, which in this region is at about 10,000 feet above the sea.

Jackson's Hole is a large open valley 35 miles long by 10 miles in width, its length being in a north and south direction. Near its head, on the west side of the river, its surface is made up of low irregular hills of moraine deposits, which are very sparsely timbered, and otherwise covered with sage and grass, the former being the dominant growth. On the east side of the river the open valley is several miles in breadth, and extends far up two large branches known respectively as Buffalo Fork and Gros Ventre Creek, which here enter the Snake from the east. In this part, the surface of the valley is but slightly broken and is well grassed, with a due mixture of sage.

Farther down the valley on the west side of the river, that is, below the foot of Jackson's Lake, the surface is largely made up of bench land, producing a similar mixture of vegetation, while the river which here flows near the eastern side of the valley has a bottom land fully two miles in width, which supports a dense growth of large willows and cottonwoods. This broad timbered bottom land accompanies the river to the foot of the valley, while the river itself gradually moves diagonally across the valley to its western side, leaving a broad grassy area on the east, below the Gros Ventre Buttes.

Nearly all of this valley is burnable, the exception being the broad, timbered bottom land along the Snake. The soil throughout is gravelly, being coarsest in the northern part on and near the morainal deposits mentioned above.

The principal parts of the courses of the branches of the river which enter it in this valley are in heavily-timbered, mountainous country. The Teton Range is heavily timbered.

Below Jackson's Hole the Snake flows through a close cañon, passing through a great mass of mountains in seeking an exit to the Snake River Plains. In this part of its course it receives three large branches from the left. The upper of these, Hoback's River, heads in a partially open valley just north of the Green River Basin, in the angle between the Wyoming and Gros Ventre Ranges. The surface of this valley is considerably broken. It is well grassed, but on the minor ridges which diversify its surface are many groves of aspens and coniferæ. This valley can be burned over, but fires would require constant attention to prevent them from destroying the timber. Below this valley the stream flows in a cañon, by which it cuts its way across the Wyoming Range.

The entire course of John Day's River, the next branch of the Snake, is in a cañon valley between two high timbered ranges, known as the Wyoming and the Salt River Ranges. It is heavily timbered throughout with coniferæ.

Next we pass to Salt River, the third large branch of the Snake. Heading mainly in the Salt River Range, we find its main stream through its whole course in a broad valley, mainly of gravelly soil and covered with a sparse growth of sage and grass. It is probably burnable, though with some difficulty.

Continuing our examination of the country tributary to the Snake on the left-hand side, we find the region lying between the valleys of the Salt and Blackfoot Rivers to consist of a mass of hills, rising one above another toward the west to a crest, and thence falling somewhat abruptly to the Blackfoot. About its crest line these hills are well timbered with coniferæ and aspens, but the slopes and lower summits are covered with bunch-grass, varied by occasional small groves of aspens, a country easily burned over.

The region drained by the Blackfoot, the next left-hand branch of the Snake of note, is characterized by an almost total absence of timber, either in the valleys or on the hills. Most of the valley portion is overlaid by a floor of basalt, on which Artemisia grows luxuriantly. The hills are covered with bunch-grass. That portion of the drainage area of this stream which lies in and among the hills and low mountains can easily be burned over. The country about its lower course, which forms a part of the Great Snake River Plains, is not as combustible, as will be shown further on.

Next we turn to the Portneuf and its tributaries. Like the Bear and the Blackfoot, this stream has a very circuitous course through and around the lava fields which obstruct it. Starting with a southerly course it suddenly turns to the westward, declining the apparently easy route southward to the Bear, and cuts its way doggedly through the Portneuf Range. Its upper valley is well grassed, as are also the hills

which lie to the eastward separating it from the valley of the Blackfoot. This upper valley, after being abandoned by the stream, continues on southward to the Bear, where it is known as Gentile Valley, and of which we have spoken above.

Passing through the Portneuf Range, the Portneuf enters, near its lower end, a broad, fine valley, occupied by Marsh Creek, the most important tributary of the river. This valley heads opposite that of the Malade, and extends, with a gradually decreasing width, 28 miles northward. Its greatest width is 12 miles. Bench land forms the greater part of the valley, and this produces mainly sage, with a small admixture of grass. Marsh Creek, the small stream which flows through this valley, has a marshy bottom land through most of its course, from one-fourth of a mile to a mile in breadth, which produces marsh grasses and willows. All the valley can be burned over, as well as the lower slopes of the Portneuf Range on the east and of the Bannack Range on the west. These ranges contain but little timber, and that near their crests.

West of the Bannack Range are the valleys of the upper waters of the Little Malade and of Bannack Creek, both open and grassy, with more or less sage, and both easily burnable.

At the foot of Marsh Creek Valley the Portneuf turns to the west for a few miles, cutting its way through a mass of high hills, then turns northwest, and, the mountains falling away on either hand, the river sweeps out into the Snake River Plains, in which it joins the Snake River.

The Snake River Plains are an enormous field of basalt extending westward from about longitude 112° nearly to the western boundary of Idaho, and from near latitude 42° north to the southern base of the Bitterroot and Salmon River Ranges. The surface is slightly undulating and is seamed with crevasses like a field of old ice. Most of the streams which enter this region soon disappear beneath its surface, perhaps to appear and disappear again. The soil is mainly a shifting sand, which, driven by the prevailing westerly winds, has collected in dunes on the eastern and northeastern border. This great area is mainly covered with sage, which grows luxuriantly, attaining arborescent proportions. In the interior and southern portions of this waste this mammoth growth of sage is the only product of the soil, but near the base of the mountains on the east and north grass gradually takes the place of sage, in a measure, and on the lower mountain slopes it monopolizes the soil to the practical exclusion of other growths.

The country along the northern margin of these plains, *i. e.*, that lying at the base of the Bitterroot and Salmon River Ranges, with the lower slopes of these mountains, can easily be burned over. The larger part of the area of these plains, however, falls in that debatable ground where it is very difficult to decide whether it is or is not burnable, economically. In some localities the Artemisia is so abundant and so luxu-

riant that there is no doubt about the case, but over most of the interior of this area the sage, though of enormous size, is not, probably, sufficiently abundant to sustain combustion without constant attendance.

The Snake River, on emerging from its long cañon, comes out on the eastern border of the Snake River Plains. Its course changes from west to south, and it flows thus across this basalt plain, keeping near its eastern margin. Near the southeastern corner of the plain the river turns west, and on that course skirts the southern border of this desert waste.

Shortly after leaving the mountains, the Snake receives a large branch from the north, known as Henry's Fork. This stream flows south along the eastern margin of the lava-field. Through most of its course its valley is heavily timbered. At its head, however, which is in a small lake in a loop of the main watershed is a small valley containing a few square miles of burnable land.

On Cascade Creek, a large left-hand branch of Henry's Fork, is a small valley, containing 20 to 30 square miles. It is open, very marshy, and grassy. Farther south, extending from the base of the Teton Range westward nearly to Henry's Fork, is a fine large valley, watered by Pierre's River, and known as Pierre's Hole or the Téton Basin. This valley has an area of open country of about 150 square miles, well grassed, but, of course, containing a due proportion of sage. Quite a large area in the middle of the valley is swampy.

With these exceptions, the country lying between Henry's Fork on the west and the Madison and the Snake Rivers on the east is very heavily timbered, with few openings of any magnitude whatever. In its northern part, it consists of a high basaltic plateau, cut by numerous cañons, while towards the south the lofty and rugged range of the Tetons separates the drainage system.

Below Henry's Fork the Snake receives no tributaries from the north for hundreds of miles—indeed, until it has passed the Snake River Plains. Then it is joined by the Malade, the Boisé, and Payette, which head in the Salmon River Mountains. Of this group of mountains little is known, as it has never been traversed by explorers, and it is but recently that mining discoveries have drawn settlement in that direction. These mountains seem to consist of a succession of ranges, trending parallel to the Rocky Mountains, *i. e.*, a few degrees west of north. The general fact that they are well clothed with timber, and that the forests descend well down into the valleys between the ranges, and into the broken country west of them is well known. Of the details of the distribution of forests and grass land it is at present unsafe to speak.

The southern section of the Rocky Mountain region is comprised in Southern Wyoming, Colorado, and New Mexico. It is characterized by the greatest elevation of the continental plateau, which rises as we pass southward from Southern Wyoming into Colorado, and near the center of the latter State attains a mean elevation of about 10,000 feet, and

thence declines gradually southward, through New Mexico, and enters the Republic of Mexico with an elevation of about 4,000 feet.

In Southern Wyoming we meet first the Laramie Range, which rises to an elevation of about 9,000 feet above the sea. At its eastern base, and far up its slopes, the fine grass of the plains extends, growing more luxuriant with the altitude. On the summit of the mountains is a straggling growth of timber, nowhere heavy. The western slope is but a repetition of the eastern.

At the western base we enter the plains of Laramie. These lie between the Medicine Bow and Laramie Ranges, are limited on the north by the latter of these ranges, where it sweeps around to the west, and on the south they extend up into the angle of the junction of the Medicine Bow and Laramie Ranges. The surface of these plains, like that of the Great Plains, is chiefly rolling, entirely bare of timber, and covered mainly with bunch-grass. Here sage becomes rather more abundant than on the east side of the mountains, but is by no means the chief product.

Passing the Medicine Bow Range, we find the country, as far west as the valley of the North Platte, to resemble in most respects that of the Laramie Plains, being open and grassy.

West of the North Platte comes a broad plateau, separating the drainage of the Platte from that of the Colorado. This broad, ill-defined divide extends from the South Pass southeastward to the north end of the Park Range. It has an uneven, rolling surface, containing many sinks, in which disappear the waters gathered over large areas.

This region, from the railroad northward to the base of the Sweetwater Mountains, and from the North Platte to the Green River Basin, is almost a desert. It has a heavy, cold, alkaline, clay soil, which produces only a sparse growth of greasewood and stunted sage. It is not a region in which the locusts are likely to breed or frequent, neither is it to be burned over easily.

South of the railroad, these plateaus extend up to the base of the Park Range. As they recede from the railroad southerly, they rise to greater elevations and become correspondingly more inviting. The soil becomes more gravelly, greasewood disappears, while a luxuriant growth of sage and bunch-grass takes its place. Should it become necessary, these plateaus can be burned over at no great expense. This improvement in the vegetation seems to commence with Bridger's Pass and extends southward to the north end of the Park Range, and along its western flank far into Colorado. The western limit of these more fertile plateaus it is not easy to point out, as they grade insensibly into a more desert region, as the elevation decreases.

The valley of the Sweetwater River is everywhere well grassed, with but little sage brush. It is mainly bench land, with a gravelly soil, and is free from timber. The river bottom has an average width of about half a mile.

South of this valley, separating it from the deserts of the continental divide, is a range of low mountains, trending nearly east and west, and known as the Sweetwater Mountains. These mountains are timbered throughout.

North of the valley of the classic Sweetwater, extending from the Three Crossings eastward to the North Platte, are a succession of low granite ridges, which are covered with a luxuriant growth of bunch-grass.

The group known as the Rattlesnake Mountains is timbered.

Turning to Colorado, we find a grand and simple arrangement of the mountain ranges on this crown of the continent. In the northern part there are two parallel ranges, trending a few degrees east of south—the Front and the Colorado Ranges. Between them lie the North and Middle Parks. The former, a nearly circular valley having an elevation of about 8,000 feet, is covered with a luxuriant growth of grass. The latter has a broken surface, being intersected by several short ranges of mountains. The valleys between them are well grassed, while the mountains are covered with forests.

In the central belt of Colorado the mountain portion is broader. West of the Park Range, beyond the valley of the Upper Arkansas, is the Sawatch, trending parallel to the others, and still further westward the groups and short ranges known as the Elk Mountains. In this portion the interval between the Front and Park Ranges is occupied by the South Park, elliptic in form, and having an elevation of 8,000 to 10,000 feet above the sea. Timber comes down well to the bases of the surrounding ranges and even trenches on the domain of the valley. The little ridges which traverse the valley are also covered with forest. Elsewhere the park is grass-covered. It is nowhere luxuriant, except in a few localities where there is natural meadow land, as in the northeastern part. There is some sage land in the lower portions of the park.

The valley of the Upper Arkansas is comparatively narrow and the part about the head of the river and the bench land everywhere are covered with forests. The open country is mainly sage land, with more or less grass.

The region of the Elk Mountains, including the narrow valleys of the upper branches of the Grand and Gunnison Rivers, is heavily timbered.

In the southern portion of Colorado, the mountain belt attains a still greater development. The Front Range, which, from Southern Wyoming, has formed the shore to the vast sea of the plains, after rising to a great height in the Pike's Peak group, suddenly falls, and disappears, while the Sangre de Cristo range, the continuation of the Park Range, comes to the front and for several degrees of latitude through Southern Colorado and most of New Mexico forms the immediate boundary of the plains. For a few miles south of the cañon of the Arkansas, a short range, known as the Wet Mountains, standing in front of the Sangre de Cristo Range, seems to form a continuation of the Front Range, the interval between this and the Sangre de Cristo being occupied by the Wet

Mountain Valley and Huerfano Park. West of the Sangre de Cristo Range lies the large valley of San Luis, beyond which is the broad and complex group known as the San Juan Mountains. These ranges are all covered with forests to the timber line. The Wet Mountain Valley is timbered except in the lower part near the Arkansas River, where the plateaus, into which it develops, are well grassed. The Huerfano Park has a very similar vegetation, being timbered near the divide and on the minor ridges, while grasses cover the lower parts.

The San Luis Valley, which contains the upper course of the Rio Grande, is a long valley, extending from Poncho Pass down into New Mexico. It has a length of about 140 miles, a maximum width of fifty, and an average width of 35 or 40 miles. Its area is not far from 5,300 square miles, of which about two thirds is in Colorado and the balance in New Mexico. Its surface is almost as level as a billiard table. In the northern part the growth is bunch-grass. As we proceed southward it changes very gradually to sage, which in turn becomes more and more stunted, and in the southern part of the valley the vegetation is very scanty, excepting at the bases of the ranges on the sides. The soil, too, undergoes a corresponding change from a gravelly soil at the northern end and at the bases of the mountains on the sides. Farther down the valley, about Sawatch Creek, the soil becomes a stiff adobe clay, and yet farther down the valley it becomes very sandy. In some places along the eastern side of the valley the sand has heaped up in drifts or dunes. This is notably the case near the Music and Mosca Passes. The sand begins near the latitude of the point where the Rio Grande enters the valley, and extends down to its southern end.

There is quite a large area of marsh and semi-marsh in the northern portion of the valley. San Luis and Sawatch Creeks entering the valley near its northern end, join and flow down the valley near its eastern border, and sink in the San Luis Lakes, near Mosca Pass. Their course in the valley, and especially below their point of junction, is sluggish and accompanied by a broad belt of marsh and of land naturally irrigated. About the lakes this area is much enlarged.

The San Juan Mountains contain no valleys of any extent. Baker's Park, an area of possibly half a dozen square miles, is the only bit of flat country to be found among them, except among their lower spurs, which will be noticed farther on, under the head of the Plateau area.

Proceeding southward into New Mexico, we find the lower limit of timber crowded higher and higher up on the mountains, so that, on the lower ranges of the southern part of the State, there is no timber whatever.

The low range of the Ratons on the boundary between Colorado and New Mexico is well timbered, though grasses extend well up its slopes. The Sangre de Cristo Range is covered with forests to its end, near Santa Fé, and the Sandia Mountains, a short group which continues its course for a few miles southward, are also well timbered. East of the

latter, on the headwaters of the Canadian, there are several small areas of timber on the plateaus, and farther south, between the Pecos and Rio Grande, the minor ranges of the Guadelupe, Sacramento and Jimenez.

The country between the latter ranges and the Rio Grande is a sage barren, depreciating in some places to a desert, excepting that close to the river, which is covered with good grass.

On the west of the Rio Grande, the mountains are timbered, with the exception of a few small ranges in the south, such as the Burro and Miembres Ranges. The country is mainly an undulating plateau, and is in most localities covered with short but abundant grass. In the northwestern corner of the Territory, however, conditions of greater aridity prevail, and the prevalent growth is sage.

The Plateau Area.

This region may be roughly defined as the area drained by the Colorado River and its tributaries. The principal of these head in the mountains, yet their courses are almost entirely in this peculiar region. Exception should be made, however, of the Gila and Williams Rivers, of Arizona, which drain a region resembling that of the Great Basin in Nevada, of low, isolated, parallel ranges, separated by desert valleys.

The plateau region includes the western portion of Colorado, the eastern and southern parts of Utah, and most of Arizona. Most of it consists of plateaus, horizontal or inclined, differing widely in elevation and in degree of natural fertility. The streams, as a rule, flow in cañons far below the surface, though in a few cases they are in broad valleys.

The Green River Basin, one of these broad valleys, has already been treated of in detail. South of this, and separating it from the characteristic plateau region to the southward, is the Uinta Range, a broad, heavily timbered mountain mass, trending east and west. This range is well timbered, the forests extending nearly to the base everywhere.

On the east and west borders of the plateau region the table lands are high, reaching along the borders of the mountains proper nearly or quite to timber line. These plateaus are heavily timbered. Among them may be mentioned the following: On the east, in Colorado, the White River Plateau, at the head of the river of that name; the Grand and North Mam Plateaus, between the Grand and Gunnison Rivers; and on the west, in Utah, the Aquarius and other high table lands, which continue the direction of the Wahsatch Range and the Kaibab Plateau, through which the Colorado cuts its Grand Cañon.

The Roan or Book Plateau, and the inclined steppes north of it, which extend across the whole region from east to west, having heights ranging from 6,000 to 8,000 feet, have considerable range in natural productions near; their crests producing mainly grasses, with occasional groves of timber, and in the lower portions sage only.

The Uinta Valley, at the south base of the Uinta Range, is described

as being a very fine valley, with luxuriant grasses in the upper part, degenerating into Artemisia near Green River.

The Grand River, after emerging from the Middle Park, flows through a region of high broken table lands, most of the way in a cañon, only occasionally emerging into a narrow sage-brush valley, nearly to its point of junction with the Gunnison. The latter stream has a somewhat more open course, with several large valleys. The uppermost of these, Taylor's Park, near the head of the stream, is pretty well covered with forests. Then follows a short cañon, from which the river emerges into the Gunnison Valley, a meeting place of several considerable streams, and of a number of valleys of greater or less width. The lower part of this compound valley is sage-covered, while the upper parts and the plateaus in the neighborhood are covered with luxuriant grasses and cottonwood.

Below this valley the river is in cañon for a long distance, while the plateaus bordering it, which rise gradually on the north to the Elk Mountains and on the south to the San Juan Range, are grassy, with groves of quaking aspens. At the foot of this, the Grand Cañon, the river emerges into daylight at the foot of the Uncompahgre Valley and flows across its lower end. This valley extends northward from the base of the San Juan Mountains, the Uncompahgre River flowing down its center. It is about 50 miles in length and 15 to 20 miles wide. It contains but little grass, except at its upper end. The growth is sage, the soil a heavy, cold clay. The bottom lands of the river are broad—one-half mile to a mile—and overgrown with bushes of various species, with quite an extensive growth of cottonwood and willow. At the foot of this valley it joins the Gunnison, which in the valley has bottom lands one to two miles in width, with a fine growth of willows.

Below the mouth of the Uncompahgre the Gunnison flows in a cañon on the left-hand side of a broad valley which produces but very little vegetable growth; and the same remark holds good, in a still more marked degree, concerning the broad valley which extends down the Grand below their junction, lying at the south base of the Book Cliffs. It is an utter desert, without possibility of amelioration save by a change of climate.

West of the Uncompahgre and Gunnison is a high plateau inclining toward those valleys and breaking off abruptly toward the southwest. It has the form of an immense spur from the San Juan Mountains, trending to the northwest. Its crest has an elevation of 8,000 to 9,000 feet; its higher part, near the crest, is well timbered, but contains many open grassy parks. Lower down on each slope the plateau is covered with sage, interspersed with piñon pine.

Farther to the westward are lower plateaus falling one below another and passing by gradations, according to altitude, into a more and more desert country. In the lowest and worst of this region the Grand and Green join, forming the Colorado.

West of the San Juan Mountains stretches the Great Sage Plain,

which extends westward to the Sierra Abajo, and south to the Rio San Juan, a broad expanse fully justifying the name, which was given to it by Professor Newberry. Here and there on this plateau are patches of piñon pine and cedar, the only tree-vegetation to be found in these arid regions. Beyond the Abajo Mountains the country presents the aspect of a plateau, arid and waterless, and almost without vegetation.

On the other side of this great plateau basin, the plateaus sloping eastward from the Wahsatch present features, in general, almost identical with those on the eastern side—the same succession of steps from the higher to the lower plateaus, the same gradation in the vegetation. There are, rising out of these plateaus, a few groups of volcanic mountains, such as the Sierras la Sal and Abajo, the Henry Mountains, and El Laté, which are partly clothed with timber, and around whose bases are belts of fine luxuriant grass, resembling oases in a desert.

The San Juan River rises in the San Juan Mountains, in a number of branches, which, flowing southward from the mountains, unite in the plain at their base, and thence pursue a general westward course to the Colorado. Among the lower spurs of these mountains, the streams have narrow grassy valleys, interspersed with timber. Away from the mountains, however, the omnipresent sage asserts proprietorship again. The river has a narrow flood plain, with groves of willows and cottonwood, but here, as everywhere in this region, grass is scarce. South of the river, however, near the boundary between New Mexico and Arizona, is an extensive group of mountains, known as the Carrisos and Tunichas, the latter name being applied to the southern portion of the range.

These mountains contain some timber near their summits, and are everywhere well grassed, while the valley of the Chelly west of the range, which forms the principal part of the Navajo Reservation, is covered with exceptionally fine grass. Beyond this region, to the westward, the country north and south of the river goes from bad to worse, a country fit only for the habitation of the rattlesnake, tarantula, and coyote.

The Colorado Chiquito heads in the western part of New Mexico, and, flowing at first westerly and then northwesterly over the Colorado Plateau, empties into the Colorado River. The plateau over which it flows has an elevation of 5,000 to 6,000 feet, terminating in a well-defined edge on the south and southwest, where it is much higher than the country beyond. In Western New Mexico and Eastern Arizona the southern border is crowned by the Datili Range. Northward the plateau stretches, a desert-like expanse, into the country above described. The greater part of this plateau, and especially the northern portion, is barren and uninviting. About the course of the river it is less arid, while the immediate valley is described as grassy and fertile, but with very little timber.

West of the river is the volcanic group known as the San Francisco Mountains, rising to a height of 12,500 feet. These mountains are densely timbered, as is also the plateau about their bases, while the tim-

ber extends westward over the plateau to its edge and down the slopes. The whole edge of the plateau is covered with forests from the mountains in New Mexico westward and northward nearly to the Colorado. This timber belt is accompanied on its northern side by a strip of varying width of pasture land, extending in some places nearly to the Colorado Chiquito.

From the edge of the plateau, the country falls rapidly towards the Gila and the deserts of Lower Arizona. About the heads of the Gila there are many groups of mountains, most of which are timbered, while the valleys and plains are well grassed. All along the slope of the Colorado Plateau the country is broken, timber occupying most of the mountains, while the valleys are grassy. As the elevation diminishes, the vegetation changes and decreases, and when we reach the lower levels, we meet with the system of narrow, parallel ranges and valleys, most of the former being grass-covered, or possibly crowned with a few scattering trees, the latter mainly barren. Of this description is the country along the Lower Gila, and its branches, the Colorado and Williams Fork. The country along the Mexican boundary in Arizona is nearly all of this description, though improving to some extent from the longitude of Tucson eastward.

The Great Basin Area and the Wasatch Mountains.

This region, which finds no outlet save evaporation, comprises portions of the following States and Territories: Oregon, Nevada, Utah, and California—itself one great basin, it comprises a number of smaller ones, which may be classified comprehensively into three, namely: that of Harvey's Lake, Oregon; of Salt Lake, Utah, and of Carson-Humboldt Lakes, Nevada.

The characteristic surface feature is that of narrow, parallel ranges, trending nearly north and south, separated by narrow, partly-filled valleys.

The most fertile regions of the basin are among the ranges in the drainage area of tributaries to Great Salt Lake, in Utah, and in the northern parts of Utah and Nevada.

Proceeding now to the drainage area of Bear River, one of the largest tributaries of Great Salt Lake, we find that its valleys, with the single exception of the upper one of all, that which extends from the base of the Uinta Mountains down to the mouth of Smith's Fork, can easily be burned over; that the ranges of hills and low mountains which separate these valleys are grass-covered, while the higher ranges, such as the Bear River and Wasatch Ranges, are covered with a somewhat sparse growth of timber.

The upper valley of the Bear, extending, as was said above, from the base of the Uinta Range northward to the mouth of Smith's Fork, with a few minor interruptions, is clothed only with a sparse growth of

stunted Artemisia. The soil is a heavy clay, and the valley is not likely to be used by the locusts as a breeding-ground.

The narrow valley of Smith's Fork of the Bear, which extends up that stream for about 20 miles, has an average width of two or three miles. This valley, with the hills on either side, is well grassed, and can easily be burned over.

A few miles below the mouth of Smith's Fork, a second large branch from the right joins the Bear. This is known as Thomas' Fork. On this stream is a large, fine valley, covered with sage and grass.

The valley of the Bear, between these streams, though not as broad as it is above, is much less inhospitable, containing more grass, and a more luxuriant growth of sage.

Between the Bear and Bear Lake lies a group of hills, which toward the south flatten out into a rolling country, which separates the valley of the Bear from the drainage of the Weber. Near the railroad, this belt of country is poor in everything except Artemisia, and even that is not sufficiently luxuriant to support a conflagration. Indeed, from the Platte Valley westward, the Union Pacific Railroad runs through one of the most forbidding sections of the whole West. North of the railroad, as this rolling country rises and becomes defined as ranges of hills, its natural productions improve, so much so that in August, 1877, nearly the whole mass of hills east of Bear Lake were burned over by fires set by Indians.

Bear Lake Valley, which may be considered to extend from the head of the lake northward as far as the Soda Springs, is a fine valley containing much grass among the omnipresent sage. This entire area, excepting that covered by the lake and swamp, can be burned over, as well as the mountain slopes on either side for at least a thousand feet above the valley, that is, to the base of the timber.

The Bear River Range separates Bear Lake Valley on the east from Cache Valley on the west, and rises to a height of about 9,000 to 10,000 feet above the sea. Above a certain elevation, which may be set roughly at 1,000 feet above the valleys, it is well, but not densely, timbered. Below the timber is an abundant growth of grass on a soil generally gravelly. South of the latitude of the head of Bear Lake this range breaks gradually down into bare hills, covered with sage and grass, which are crossed by the Weber in its westerly course to Great Salt Lake. These hills I should judge to be burnable.

The valley of the Weber, which is, for the most part, merely a notch cut in high hills, widens out at the east base of the Wasatch Range into a large fertile basin, well settled by Mormons. This valley is easily burnable.

Returning to the Bear, at Soda Springs we find that it makes an abrupt turn back upon itself around the north end of the Bear River Range. Below this bend the river flows first through Gentile Valley, a small valley between the Bear River and Portneuf Ranges. This, like

most of the valley country in this region, is covered with sage and grass.

Then, after a short cañon, the Bear flows out into Cache Valley, the "Garden of Utah." This beautiful, fertile valley is about 50 miles in length in a north and south direction, by 12 miles in the opposite direction. It lies between the Bear River and the Wasatch Ranges, and has an area of about 600 square miles.

The Bear flows half-way down this valley, then, turning west, it cuts its way through a low ridge, which here represents the Wasatch Range, and thence flows off southward to Great Salt Lake.

The surface of the valley slopes gently inwards from the base of mountains or hills which limit it. Near the river, and extending for two or three miles on each side of it, is fine meadow land, sufficiently moist to admit of cultivation without artificial irrigation. The natural productions of this part of the valley are coarse marsh grasses, while the drier parts of the valley are covered with bunch grass, with a due admixture of sage; though it must be said that in this case there is much less than the ordinary proportion of this latter staple. The whole valley, with the lower slopes of the mountains and hills surrounding it, can easily be burned over.

Cache Valley is well settled. The population, which in 1870 amounted to 8,229, are nearly all of the Mormon persuasion, and are almost exclusively engaged in agricultural pursuits. A very considerable part of the arable area of the valley is now under cultivation. The cultivated areas extend in strips from the base of the mountains down nearly or quite to the river, and are irrigated mainly from the large lateral branches of the Bear.

The Wasatch Range forms the eastern wall of the Salt Lake Valley. This range, which in its middle and southern part is broad and very complicated, in its northern part, *i. e.*, north of the gap of the Weber River, is very much narrowed, being reduced to a single ridge; and just south of the Gates of the Bear it practically disappears, being represented at the Gates only by a low ridge. Farther north this ridge develops suddenly into a high range, known as the Malade Range, which forms a part of the western wall of Cache Valley. West of it lies the valley of the Malade River, stretching southward to the northern shore of the Great Salt Lake. This valley is somewhat more arid than that east of it, but yet supports a very good growth for pasturage. Meadow land is found in considerable amount near the streams in the northern part of the valley and along the shores of Great Salt Lake. As in Cache Valley, these are covered with coarse marsh grasses. The whole valley is burnable.

The hills west of Malade Valley, the Blue Spring Hills, are almost entirely devoid of timber, and are covered with excellent grass, with a slight admixture of sage. They can easily be burned over. Such is also the case with the valley next west, known as the Blue Spring Val-

ley. This valley resembles that of the Malade in most essential features of vegetation.

Thence westward, the country in Northern Utah and Nevada and Southern Idaho and Oregon consists of a similar succession of narrow ranges and valleys, the former grassy, or containing a sparse growth of inferior timber, while the latter are poorer in grass and richer in sagebrush.

Along the Central Pacific Railroad the vegetation is very scanty as far as the head of the Humboldt, and grows still worse to the southward. This is the country which formed a part of the bed of the fossil lake Bonneville, and, while the water has departed, the solid portions, in the form of saline incrustations, remain in immense amount, covering thousands of square miles with a white, shining floor of alkali. Of course, here it is impossible that vegetation should grow. Even on the few groups of mountains, which rise here and there like islands from a placid sea, there is little vegetable growth.

The country along the western base of the Wahsatch Range, extending thence to the Great Salt Lake, is a fertile, well settled region. The inhabitants are Mormons, and their occupation farming. At the base of the mountains a continuous line of springs breaks forth, which, with the Weber and Ogden Rivers and Box Elder Creek, water nearly the whole of this strip.

The lower slopes of the mountains produce a fine growth of bunch grass, while on the flat below sage becomes a component to some extent of the vegetation. Along the shore of the lake there is much marshy land, producing reeds and coarse grasses. All this strip of land can be burned over easily.

The valley of the Jordan was originally an expanse of sage, bordered at the base and on the lower slopes of the Wahsatch Range by fine pasturage. The grass improves southward, among the valleys on the tributaries, to the Utah Lake, and on Sevier River, while the mountains and higher plateaus are timbered.

On the eastern slopes of the Wahsatch Range there are several fine valleys, where the plateaus break off against the base of the mountains. One of the largest of these is known as Castle Valley.

Comparatively few of the ranges of Nevada are timbered, and most of those are but sparsely covered by a stunted growth of desert species, such as Piñon pine and cedar. Of these the Toano, Goshute, East Humboldt, Diamond, Piñon, Snake, Antelope, and Cedar Ranges in the eastern part, the Pancake, Hot Creek, Monitor, Toyabe, Desatoya, and West Humboldt in the center, and the Walker River, Sierra Nevada, and Pyramid Lake Ranges in the western part contain nearly all the timber of the State. The other ranges are grassy, or, in the south, covered with Artemisia, or are barren.

Few of the valleys contain grass enough to be of economic value, except in the northern part. Most of them are waterless and covered

with stunted sage, or are barren. It is unnecessary to go into details regarding them, as the accompanying map expresses them better than any description could do it.

There is a plainly marked gradation southward in the vegetation.

Of the Mojave Desert, of Southeastern California, little need be said, save that it is almost without vegetation, excepting at a few isolated spots, where springs break through to the surface, forming small oases, and the narrow belt along the Mojave River. On the borders of the San Bernardino Range, however, there is a narrow belt of grass, while the higher portion of the range is well timbered.

PREVENTIVE MEASURES IN THE PLAINS AREA.

From the foregoing account of the topographical and botanical characteristics of the different areas in the Permanent Region, taken in connection with what we have said both in this and our previous report, it is obvious that the plains area transcends in importance all the other areas here considered, from the locust point of view.

The surface conditions under which *Caloptenus spretus* breeds in the greatest abundance are a loose, warm, gravelly soil covered by a tolerably luxuriant growth of grasses, such as are found in most river bottoms; in the northern part of the plains of British America, along the bases of the mountain ranges, and in the high mountain valleys. Such areas are of greater extent in the northern portion of the region which we have described, becoming very much more limited in the Southern States and Territories.

While it is quite possible that the insects may breed anywhere on the plains, it is certain that, as shown in our first report, the more fertile portions of this area, and especially that great fertile belt between the two Saskatchewans, in British America, is the principal source of the swarms which at times sweep down upon the prairies. The extent of these breeding grounds in British America may be approximately estimated at about 100,000 square miles.

In Montana there is a broad belt at the eastern base of the Missouri Range, extending down the branches of the Missouri River for long distances. The country about Sun and Teton Rivers is very luxuriant, even as far as their mouths. The Gallatin Valley is luxuriantly grassed. The lower slopes of the Judith and other neighboring groups of mountains, the country about the base of the Yellowstone Range, the valleys of the Jefferson and its branches, with the hills in their neighborhood, may also be looked upon as breeding places of the pest. On the western or Pacific Slope, the valleys of the Deer Lodge, Bitterroot, and Hellgate, and of several of their branches, fall into the same category, as also the valleys of the Kootenai, and of Flathead Lake.

The bottom lands of many of the streams of the plains, though comparatively narrow, afford probable breeding grounds. Those of the Missouri are quite narrow, but on the Yellowstone they have an average

breadth of more than a mile. These bottom lands are fertile and, where not covered with cottonwood and willow timber, are clothed with luxuriant grasses. The total area of the more fertile portions of Montana may be roughly estimated at 26,000 square miles.

In Washington Territory, all of that portion represented on the map, with the exception of that occupied by forests, is covered by luxuriant grass. Its area may be set down at about 7,000 square miles.

In the eastern part of Oregon the more fertile portions consist principally of comparatively small valleys in the Blue Mountains, such as the Grand Ronde. They sum up about 2,000 square miles.

In Idaho the more fertile grass lands are very widely scattered, consisting mainly of more or less narrow belts about the bases of the Bitterroot, Cœur d'Alêne, and Salmon Mountains, and in the mountains in the southeast corner. Altogether they sum up about 10,000 square miles.

In Western Dakota the most fertile grass regions are on the north, east, and south of the Black Hills. Luxuriant grass extends northward for many miles from their base, and eastward covers nearly all the country between the forks of the Cheyenne. The area may approximately be estimated at about 5,000 square miles.

In Wyoming the principal breeding grounds are probably the following localities: The plains east of the Laramie Range, the Laramie Plains, the country about the base of the Park Range, the borders of the Wind River Valley and the Green River Basin, the valley of the Sweetwater and the Granite Hills just north of it, the eastern base of the Yellowstone Range, and the Big Horn Mountains. The total area of the Territory may be roughly estimated at 12,000 square miles.

In Colorado the following regions are the most fertile: The plains at the eastern base of the Front and Sangre de Cristo Ranges—this fertile region extends eastward to a varying distance in different latitudes and altitudes; the Parks, North, South, and Middle, with the northern end of San Luis Valley; the plateaus about the cañon of the Arkansas and the Gunnison Rivers, the Wet Mountain Valley and Huerfano Park, and also many small areas among the mountains, which cannot be specified, but which, in the aggregate, swell the total considerably. The total area is probably about 15,000 square miles.

Proceeding southward, the area of luxuriant grasses becomes markedly less. In New Mexico it probably does not exceed 5,000 square miles, or about one-third that of Colorado. This is found at the east base of the Sangre de Cristo Range, and about the Raton Hills, along the Rios San José, Puerco, and Vaca, in the Valles Mountains, and on the plateaus about the head of the Colorado Chiquito.

In Utah the area is about the same. It is located mainly in Cache Valley, on the narrow ranges of mountains west of it, in the narrow strip of land between the Wahsatch Mountains and Great Salt Lake, in the upper valleys of the Sevier River, the Uinta, Castle, and Grass Valleys, and about the bases of the Henry Mountains and Sierra la Sal.

In Arizona the fertile area is still farther circumscribed, being not more than 3,000 square miles. It is found only on the higher plateaus, the Uinkaret, the Paria, and Sand Dune, in the valley of the Rio de Chelly, and in Nine Mile Valley.

In Nevada the area is about the same, and is nearly all confined to the mountain ranges in the northeast and a few valleys on the northern border, such as that of Quinn's River.

It would seem, therefore, that of the 400,000 square miles embraced in the Permanent Region, but about 177,000, or about one-third of the whole, is of such a character as to permit excessive multiplication of the locust. Some 19,000 are contained in Washington Territory, Oregon, and Idaho, where the movements of the locusts are neither so regular nor controlled by the same laws as are those of the hordes which breed in the Northwest, east of the mountains. It is noticeable also that in British America there is more land favorable to permanent breeding and excessive multiplication than in all the rest of the Permanent Region, and that the country in Montana just south of the boundary line furnishes the next largest amount.

We will therefore at once consider in how far each of the preventive measures is practicable in this plains area, and the results that may be expected from liberal government support of either.

1. ENCOURAGEMENT TO SETTLEMENT.—That every encouragement to the settlement of the Northwest should be given we have endeavored to show in Chapter II. Aside from the fact now generally conceded, and which the experience of the last quarter of a century seems to demonstrate, that the climate is materially modified and rendered more humid by settlement and cultivation, it is also a self-evident fact that in proportion as the farming population increases and pushes into the region where the locust permanently breeds, in that proportion will the extent of those permanent breeding grounds be reduced by man's necessary efforts in self-protection.

Compared to the excessive injury from locusts which formerly prevailed in Central Europe, there has been great freedom from their ravages during the past century, a fact evidently due in large part, if not entirely, to the increase of population and settlement. With a dense population it is easy to adopt preventive measures by destroying the eggs and young of invading swarms. So also in Utah the injury and fear of injury on the part of the Mormons have decreased in proportion as population and settlement increased.

The belief is very general among those who have studied the subject that the planting of tree belts and forests tends greatly to ameliorate a dry climate by causing rain precipitation where otherwise the clouds would pass over and away, as well as by more nearly equalizing the normal annual rainfall, which, on our plains, is generally borne to earth in torrential storms, which do comparatively little good. We have no doubt but that the belief is well founded, for careful researches carried

on by M. Fautrat in France, and recently recorded in the *Comptes Rendus* of the French Academy, strongly confirm the belief and the position generally maintained, and well set forth in Marsh's "Man and Nature"; but it would seem equally true, from some of the most careful researches that have been made on the subject, that the breaking and cultivation of the soil and planting of other forage and cereal crops have also a marked effect, probably as great as the cultivation of trees, in producing the same effect. This is the experience of M. Tisserand,[341] and has been strongly confirmed recently by Mr. H. R. Hilton, in a paper read before the Kansas Academy of Science, on Rainfall in its Relations to Kansas Farming. He maintains that the actual amount of rain which falls in a given district is not the measure of the ability of that district to withstand drought, but rather the amount absorbed by the soil and held for the use of plants. The gulf winds which blow over Kansas are as humid as those which reach farther east, but the rainfall in that State is less because the soil offers less favorable conditions for precipitation. He shows clearly that the cultivable area is increasing with the advance of settlement, and in proportion as the soil is plowed deeply and the area of ponds of water and the cultivated fields of growing crops extends. Settlement, therefore, providing it be not purely pastoral, will not alone cause a decrease in locust injury by virtue of the number of locusts, whether in or out of the egg, that may be slain, but indirectly, by causing an increase in the moisture of the country, since the migratory locust is essentially a denizen of arid regions. In a recent trip to the Northwest, Professor Thomas was so deeply impressed with the important bearing which the settlement of Dakota had upon the locust question in Minnesota that he communicated to Governor Pillsbury the following views, which we give at length, because the same views are equally applicable to much of the rest of the plains area:

According to promise, I give here my reasons for believing that in time Minnesota will be comparatively free from locust invasion. As stated in my verbal communication to you, no one acquainted with the history and habits of these insects, and who has witnessed their flights as in 1874 and 1876, expects or hopes to find any means of suddenly exterminating them or stopping their flights. If this is ever accomplished it must be done gradually and by making use of such natural forces as may be partially within man's control.

The facts ascertained by the commission in reference to the long series of invasions from 1873 to 1877 led me to believe that there was but little hope that your State would ever be relieved of this fearful pest. This opinion was based upon the fact of their apparent stronghold upon and long continuance in the southwestern portion of the State; and the belief I then entertained, that a large portion of Dakota east of the Coteau of the Missouri could never be made an agricultural section on account of its supposed arid condition.

A fact then suspected, which will hereafter be explained, and what I have seen and ascertained the present year in reference to the agricultural capacity of Eastern Dakota have served to materially modify my former opinion and to cause me to hope and, I may say, believe, that the day is not very far distant when Minnesota will no longer have reason to fear the invasions of the locusts.

[341] *Cf.* Conclusions of M. Tisserand, as given in the report by John P. Reynolds on the State of Illinois at the Universal Exposition of 1867 at Paris, p. 124.

By reference to the map of your State, prepared by your Geological and Natural History Survey, showing the locust areas therein for the years 1873-'76, it will be seen that the southwestern portion of the State was the part most continuously affected. Other facts ascertained by the commission indicated some peculiarities in this respect in reference to this section not observed in other parts of the State or in the States south. These facts attracted my attention and induced me to seek and, if possible, to find out the cause for these peculiarities; in other words, to find why the locusts hung longer and more continuously around this section than in other portions of the State. This, I now believe, is to be found in the elevated region called the Coteau of the Prairies, which affords topographical and climatic conditions more nearly adapted to the continual existence of the locust than other portions of the State. If I am correct in this opinion we have here one factor which must be taken into consideration in the discussion of this locust problem so far as it relates to your State and the adjoining section of Dakota.

As before intimated, I had formed the idea that the more elevated portions of Eastern Dakota, for instance, those lying along and bordering the valley of James River, were too sterile and arid ever to be used for agricultural purposes; that in fact but a narrow strip alone along the James River could be made productive by means, in part at least, of irrigation. The facts seen and ascertained the present year have in a large measure dispelled this unfavorable opinion. I am aware the present year is a very favorable one, and one that cannot be considered as a type of the seasons in that section; but it shows, I think, conclusively, that a very large portion of this section of Dakota can and will ultimately be made to sustain a large agricultural population. For even allowing quite a heavy discount on the present crop there would still be sufficient to justify farming in this region; and wherever this is the case, and the process of farming is so easily carried on as here, the section will ultimately be settled up.

In this fact I think we find a second important factor to be considered in discussing this problem.

A third possible factor is the supposed climatic change believed by many to be going on. Although I have not included this item in the present consideration, and cannot say that I have been converted to that view, but look upon these changes rather as cyclical, yet there are some reasons for believing that an unusual change of some kind is now going on in the seasons in the Northwest; what the ultimate result will be I am wholly unable to predict, but so far, at least, it is favorable.

Leaving the last item out of the discussion let us see what hope is to be based on the other items.

It is reasonable to believe, in fact we may assume as evident, that the farther west settlements are pushed continuously, that is without extensive breaks, and the denser they become, the greater will be the tendency to hold back, so to speak, the locust swarms; that is to say the advanced cultivated fields will bring them down, in part at least, and, supplying their appetites, prevent them from advancing further eastward; their temporary nesting grounds will also be disturbed, and thus their advance retarded.

While this is true theoretically, the experience of the years 1874-'77 may cause many to doubt its correctness in reality. It is true that swarms drive on southeast in their invading flights over broad and extensive settlements, as, for example, over Nebraska into Iowa and Kansas, and occasionally even into Missouri and Texas; but after all, though not brought to public notice, the fact is that Northern or Northeastern Nebraska often receives the smaller invading swarms and suffers the injury when the central and southeastern parts are entirely exempt. Other facts might also be cited to prove that the statement above made is true as a general principle. But Minnesota is somewhat peculiarly and favorably situated in this respect. The locust swarms, as a very general rule, sweep down from the northwest in a south and southeast direction, and, as it requires a much less opposing influence to turn them slightly away from their course than to stop them directly, the chances are much more in favor of localities thus situated than if placed directly in the line of their usual course.

As bearing upon this point and tending to confirm the opinion here advanced, I refer you to the chapter on chronology in the first report of the commission. In this it will be seen that the great invasions of 1876 passed southward along the west side of Manitoba not entering that province and not entering Minnesota (that is depositing eggs) north of Clay County, whereas in 1856 they penetrated eastward in this latitude to Cass County.

By reference to the map of Minnesota before alluded to you will see that the areas of egg-deposits in 1873–'74 and 1875 were in the extreme southwestern part of the State.

From these facts, and from many others which might be mentioned, I conclude, and, as I believe, correctly, that if (with the conditions hereafter mentioned) the eastern part of Dakota, from the west line of the James River Valley to the eastern border of the Territory, can be settled to a moderate extent with a farming population, the locust invasions will be largely diverted from your State. The farther these settlements extend northward, and the more extensive and dense they become, the greater the benefit.

In this connection I may add that while in Winnipeg I was informed that the Souris or Mouse River section is proving to be a better agricultural area than was supposed; that coal has been found there, and that land is now being surveyed preparatory to settlement. If this is found to be correct, and the settlement should become extensive, it will aid in the direction indicated.

The benefit to be derived by Minnesota from the settlement of Eastern Dakota does not by any means consist wholly in the fact that it will then offer the first attractions to the invaders. Dakota, east of the Missouri, has evidently long been a kind of camping-ground for the locusts. Not simply a stopping place for a few days of invading swarms that then passed onwards, but a temporary breeding ground, where the invaders of one season would deposit their eggs, the young from which, if the next season proved favorable, would pass onward to the southeast or east. I am fully aware that invading swarms from Montana and even British America sometimes extend their flights in a single season to Iowa, Nebraska, and Kansas; but I am also aware of another fact, not so generally known, that, in what are considered non-locust years, the shorter movements—as from Montana into Dakota, from British America into Dakota, and from Western to Eastern Dakota—are going on, to a greater or less degree, according to the seasons, and that for a season or two preceding the great invasions they are more than usually active in these movements. For proof of this I refer you to our First Report, pp. 82 to 92, and Appendix, pp. 243, 244.

A settlement of this section of Dakota will have a tendency to interrupt these movements and prevent the insects from using it as a temporary breeding-ground. That this portion of the Territory could be considered a truly permanent breeding-ground of the Rocky Mountain locust I now consider improbable, for I do not believe they can remain permanently in any section where farming can be carried on continuously without any aid from irrigation, unless it be far northward in British America, or in some very elevated section. But, possessing largely the topographical and climatic characteristics adapted to the life, habits, and perpetuation of the locusts, they retained their hold here much longer than in the more truly temporary regions of Central Minnesota and of Iowa, Nebraska, Kansas, &c. As before stated, the elevated and treeless character of the Coteau of the Prairies has evidently furnished the pests with a temporary breeding-ground, and will explain the reason for their hanging so long in the southwestern part of the State.

Is it possible to do anything to this coteau that will render it less adapted to this purpose? If it is possible to clothe it with timber, I answer, emphatically, yes. Cover it with a forest and it will cease to be a rendezvous of the pests, and the influence of this changed condition will be felt in this respect down to the extremity of the long and gentle slopes extending into the southwestern counties of Minnesota. No one supposes that any artificial forest that can be placed here will form such a barrier as to stop the flight of a locust swarm; but it will prevent it from being a nesting-place.

From all I could ascertain during my short visit to that section I think that by beginning with cottonwood the elevated ridges and plateaus of this coteau might ultimately be clothed with timber, but this is a question that must be decided by the horticulturists. If it can be done, and the settlement of Eastern Dakota goes on as rapidly as at present, I am thoroughly satisfied that locust visitations to Minnesota will grow less and less frequent, and the numbers decrease. In other words, the battle with the armies of these little foes will be transferred to a great extent to the valleys and plains of Eastern Dakota.

It is therefore to the interest of Minnesota that the settlement of this part of Dakota be pushed forward as rapidly as possible; that the numerous lines of projected railroad through this area be completed at as early a day as possible. Nor will this be less beneficial to this portion of Dakota, for the more extensive and more dense the settlements become, the less difficult will the contest be.

But in order to obtain the full benefit of this settlement there are three conditions which I think it will be necessary to observe.

First. The clothing of the higher portions of the Coteau of the Prairies with timber, and I think it would be well for Dakota and Minnesota to apply to Congress for this purpose. It is the only assistance in this respect they will have to ask of the government, and whether the result so far as the locusts are concerned be as anticipated or not, any reasonable appropriation made for this purpose will not be uselessly spent if the work is properly carried out, for the timber will render the land more valuable, and it is more than probable that it will have at least a slightly beneficial effect upon the climate. It is proper that I should remark, in this connection, that the present Commissioner of Agriculture, General Le Duc, suggested this some two years ago for another purpose than that now proposed.

Second. Tree-planting should be carried on as extensively as possible in all the settlements.

Third. The lakes, ponds, and even marshes scattered over Western Minnesota and Eastern Dakota should be carefully preserved. This is an essential item in the future prosperity of this entire region. Drain these or dry them up, and the day will surely come when this entire section and Northern Iowa will be as arid and barren as the great plains of the West. Every pond, swamp, or marsh drained is to that extent an injury to your State.

From whence comes the moisture that supplies your prairies? From the great lakes that lie along your northern border from Superior to Winnipeg. Arising from these it falls first into or feeds the lakes and marshes of your northern timbered section; thence by another step it spreads southward over the prairie region, feeding the numerous lakes and ponds of that section. The evaporation from these not only assists in drawing down the moisture which would otherwise be dissipated, but assists in spreading it farther southward and southwest. Drain the latter and all this beneficial influence will be lost, and step by step the water area will be diminished and the amount of rainfall lessened.

The broad and extensive marshes of the Red River Valley, between Saint Vincent and Saint Boniface in Manitoba, are of great value to the lands bordering the upper or southern portion of that valley, and if drained will certainly tend to lessen the rainfall over the beautiful and productive plains between Red and James Rivers.

I urge this matter upon your consideration because the history of the world shows that in this respect man has generally acted with consummate folly. In all the writing and discussions in reference to rainfall and supply of moisture the all important item—area of evaporating surfaces—seems to have been overlooked. Preservation of forests, planting of trees, &c., have been urged, and properly too, but maintaining or enlarging the area of water or evaporating surface seems to have been entirely forgotten. It is possible perhaps to accomplish this, in part at least, by appropriate State legislation. But simply refraining from draining is not sufficient. These little bodies of water should be surrounded by fringes of shrubbery and trees which should never

be removed. If even the little streamlets flowing here and there through the prairies were generally fringed with thick shrubbery so as to partially protect the surface from the sun, this would aid much more than is supposed in retaining and distributing the moisture.

It would require too much space for me to attempt to give in full here the reasons and arguments bearing on this point.

In conclusion, allow me to say that I feel confident that if proper measures are taken and proper efforts are made in the directions indicated in this communication, the citizens of Minnesota may feel assured the day is not far distant when the grasshopper will no longer be "a burden" upon the agricultural prospects of their beautiful State. That there will be occasional visitations is to be expected, but I believe the day of severest trial has passed; the long and severe visitation of 1873-'77 will probably never be repeated unless, through want of care, your country is allowed to become arid and dry, or some climatic change over which you can have no control should bring about this condition.

I might add something in reference to the system of farming which I think would be advantageous in reference to the locust problem, but this communication is already long; and moreover I am well aware that farmers are not much disposed to listen patiently to suggestions in reference to their particular profession from one they consider a mere theorist. I therefore refrain.

I am glad I can speak thus hopefully of the future of your State. I have written conscientiously and not for the purpose of flattery. The views here given have been formed after a somewhat lengthy and careful study of the subject in all its bearings.

2. ENCOURAGEMENT TO RAILROADS.—Many persons believe that the building of railroads through almost rainless regions—the breaking of soil, laying of rails, stretching of wire, and consumption of fuel incident thereto—has a beneficial effect in ameliorating the climate in one way and another, but particularly in causing more frequent precipitation of moisture. They cite, in confirmation of this belief, the constant extension of settlement and of the cultivable area westward along the lines of the Kansas and the Union Pacific Roads; for the country is now settled along these roads far into what was formerly called the "American Desert," or into regions which but a few years since were considered uninhabitable from the fact that farming was supposed to be impossible there. The results are doubtless more due to the breaking and cultivation of the soil as above explained (p. 303); but whether or not railroads have this supposed influence, it is certain that they greatly benefit such a country in many other ways, and they should be encouraged as much as possible, not only because they conduce to the settlement of the country they traverse, but because they also facilitate communication between sections, and, in the country under consideration, will render more complete the system of warning, which we shall presently consider. We believe, therefore, that it is to the interest of the Government to encourage the building of railroads in this sparsely settled region and would emphasize what has been said on page 21.

3. IRRIGATION.—It is well known that in most of the country west of a line passing through Dakota, Nebraska, Kansas, Indian Territory, and Texas irrigation is almost universally necessary for success in agriculture. The eastern boundary of this "arid" region consists of a broad

belt of *debatable* land, which has a width of perhaps two degrees of longitude. In favorable seasons this belt may be cultivated without irrigation, while in dry seasons the whole area may require artificial watering. This belt traverses the eastern part of Dakota, gradually moving westward as it nears the southern border. It passes across Nebraska nearly in its center, and continues nearly due south, crossing Kansas slightly west of its middle line. It crosses the western part of Indian Territory, and in Southern Texas gradually trends to the eastward, reaching the Rio Grande not far from its mouth.

From this arid region must be excepted the greater part of Washington Territory, especially the western portion, that part of Oregon lying west of the Cascade Range, and the northern half of California lying west of the Sierra Nevada. Within the region thus excepted the rainfall is sufficient to insure crops.

Within the area designated as "arid" there are small districts which, owing to the conformation of the local topography, enjoy sufficient rainfall for the needs of agriculture. But these cases are too few and limited to be considered in this connection.

Here, then, is an area of 1,400,000 square miles, or nearly one-half the area of the country, exclusive of Alaska, in which the important industry of agriculture is dependent entirely upon irrigation. Without water the land is of value only for its sparse covering of grasses; is useful only to the stock-raiser; its productive capacity is reduced to about one-hundredth. The question of irrigation, therefore, is one of paramount importance, inasmuch as the future of nearly one-half of the country depends in a great measure upon it. It is a subject of State and national importance. Throughout the greater part of this region the extent of the arable land is purely a question of the amount of water available for irrigation. The area of land suitably situated in other respects for agriculture is several times as great as can be supplied with water. Probably not a hundredth part of the water which flows in the streams of the West need run to waste for want of land fit for receiving it; while, on the other hand, it is probable that, using all the water to its utmost capacity in irrigation, not one-fifth of the land which is suitably situated for it can ever be irrigated.

It becomes, then, a question of water rather than of land. Of the two the former is all-important; the latter has the smallest actual value. Without water the land cannot be given away; with it, it becomes as valuable as the rich prairies of Iowa. The measure of success already obtained in the endeavors to reclaim the Arkansas Valley to profitable agriculture, as the Hon. F. G. Adams has shown in a recent paper before the Kansas Academy of Science, is a sufficient warrant for much more careful surveys by the government of the river valleys of our Western plains with the object of increased irrigation.

There are two sections of the country which urgently require the protection and assistance of the national government for their agricul-

tural interests. One, the great West, we have already treated of at length. The other is the low lands of the Mississippi Delta. Every flood in the great branches of the Father of Waters carries destruction to thousands of plantations in the South, destroys hundreds of thousands of dollars' worth of property, and leaves in its path deadly miasmas for the destruction of human life. A system of levees, constructed at an expense of millions, affords but partial protection, and costs large sums each year for repairs.

These levees can be regarded, in the light of modern engineering science, but as a temporary auxiliary in the great work of protecting this rich alluvial region. The true way of solving the difficulty of curbing the violence of this great river is to strike at the root of the matter, and *prevent the floods*. The only way to effect this is by the construction of reservoirs wherein the flood waters shall be gathered, and whence they shall be allowed to flow in a quiet, orderly manner. This is no new idea. It was proposed many years ago by Ellet, but at the time was buried beneath the ponderous arguments of the Engineer Corps.

Not long ago it was revived under their own auspices, and the experiment of controlling the Upper Mississippi by reservoirs in the lacustrine region of Northern Minnesota is now being tried. It will be, measurably, a success.

This work should be extended to the Missouri, the Plattes, the Arkansas, and the Red Rivers, and it should be combined with the irrigation interest in such a way as to serve the latter as perfectly as possible. These streams and their upper branches should be turned into reservoirs at or near their points of exit from the mountains. These reservoirs should be, collectively, of sufficient capacity to hold all, or nearly all, the vast amount of water brought down by the melting of the winter's snows. The construction of a series of small, rather than one or two large reservoirs, will probably prove most beneficial, both as costing very much less, and also because the water would be placed more conveniently for use, thus lessening the length and consequent expense of the irrigating mains and secondary ditches. There are, on or near the course of every considerable stream, among the swells and billows of the plains near the base of the mountains, an abundance of hollows suitable for reservoirs of greater or less magnitude. No great canals need be constructed, as sufficient reservoir capacity can be obtained on or near the streams, and all the water can be used by a comparatively narrow belt of land in close proximity to the rivers, where the land is more level and consequently better suited for irrigation than near the divides. Other things being equal, the water should be used on land near the mountains rather than on that far away, in order to avoid loss by evaporation and sinking, or "seepage," as far as possible.

As the land is placed under irrigation, it might be sold by the government with the water-right attached, *i. e.*, the right, in perpetuity, to the use of sufficient water for the irrigation of the land, at the rate of a

certain number of cubic feet per second for each section of land. An annual tax, also, should be levied for the maintenance of the works. This would be a mere trifle compared with the original cost of the water-rights.

By thus taking the matter in hand, the general government will not only promote the welfare of the country by largely increasing its productive capacity, but will increase its own returns from the public lands immensely. It might, if properly managed, be an extremely profitable speculation for the government.

The cost of irrigation per acre differs materially in the various sections of the West, owing to the greater or less expenditure required for bringing the water to the land, and also, of course, according to the amount of water used. The general range is from $1 to $3 per acre annually, and the average is not far from $2. As a general thing, the water is supplied to ranchmen by ditch companies, who charge them a fixed price per year. The unit of measurement is commonly the "miner's inch," though this is gradually giving way to the simpler unit of the "second foot." Many companies, however, charge by the acre, ranging their rates with the different crops cultivated.

We have already laid stress on the importance of increased settlement and cultivation of the Northwest as a means of checking locust increase and of preventing the disastrous incursions of these devouring pests into the more moist and fertile Mississippi States; but as irrigation is, in the larger portion of the region, absolutely indispensable to this settlement by an agricultural population, its importance cannot be overestimated. As will be seen from our First Report, irrigation has not only this important indirect bearing on the locust question; it has also a direct bearing, for it affords one of the chief and most satisfactory means of destroying the young locusts, either by drowning them out, as in submersion, or by killing them with kerosene floated down the ditches. It is therefore by encouraging and extending irrigation that the national government can most satisfactorily act so as to permanently lessen the locust evil, and we cannot too strongly urge upon Congress the desirability of wise and patriotic action in the matter. So important, indeed, do we deem this question of irrigation that we have endeavored to get at some approximate estimate; first, of the amount of land redeemable by it; second, of the cost of redeeming said land; third, of the best plans to be pursued. Upon these and other points we have obtained the following report from Henry Gannett, E. M., whose experience adds weight and importance to his views:

To illustrate the great value of water in the arid region, we may say that a continuous flow of one cubic foot of water per second, throughout the growing season, means 200 acres of land saved from the desert; it means, also, 30 bushels of wheat per acre, a total of 6,000 bushels, worth perhaps $4,500. The utmost economy in the use of water is, then, the great desideratum, as every cubic foot saved insures to agriculture 200 acres, more or less, of the best of land. It is perhaps unnecessary to say that the system, or rather want of system, at present in vogue in this region is decidedly the

reverse of economical. It partakes of the prevalent western spirit, by which the cream is skimmed from every source of natural wealth, which is then abandoned. "After us the deluge." In Colorado, irrigators use five times as much water as is needed, in Utah two to three times as much, and in the great valley of California it is used as wastefully. But in the arid regions of Southern and Southwestern California, where the ranchmen are Mexicans, who have had centuries of experience, and where the water supply is very limited and is all used, the utmost economy prevails, and probably the "duty" of water is carried to the highest possible extent.

But it is not alone the lavish use of water which should be criticised. The want of a general plan for the distribution of the contents of the larger streams will inevitably, in the near future, cause great waste of arable land. The let-alone policy is the only one in practice at present. By it each ranchman, or each ditch company, helps himself to water wherever he may find it. The only rights are those of priority of possession. The result of this happy-go-lucky mode of procedure is that the water is distributed to the land by no means in the most economical manner. As a general thing, the lands immediately adjacent to the streams—the bottoms—are first taken up, and they, monopolizing the water, render valueless all the land back of them, although the contents of the stream may not be by any means all used.

The general and the State governments are perfectly cognizant of this condition of things, yet practically nothing has been done by them. With the easy indifference of the optimist, the government has watched this waste going on for the past two or three decades, and has done nothing to correct it. A move in the right direction was made in 1873, when Congress authorized a commission, under a small appropriation, to make an examination of the Great Valley of California, with a view to forming a general plan for irrigating it. The commission made as full an examination as was possible with the limited means at its command, made its report—a very able, though by no means an exhaustive one—and there the matter ended.

In 1874, Prof. George Davidson, of the Coast Survey, was sent, under the auspices of the general government, to study the irrigation systems of foreign lands. He made a brief study of the methods in use in India and several European countries, and the results of these studies were embodied in a report to the Secretary of the Treasury, constituting Ex. Doc. 94, Forty-fourth Congress, first session.

The Geological Survey of the Territories, under Dr. Hayden, has made an examination, not by any means exhaustive, however, of the irrigable lands of Colorado, bringing out, as a net result, that 7 per cent. of the area of the State, or a little over 7,000 square miles, can be irrigated at once from the streams without having recourse to the reservoir system.[342]

The survey of the Rocky Mountain region, under Maj. J. W. Powell, made a similar examination of the Territory of Utah. The result of this work showed that but 2.8 per cent. of the Territory could be irrigated.[343] This, in the opinion of the writer, is too small, owing to some conclusions of Major Powell, to be hereafter noticed, which are believed to be erroneous.

The above embrace practically all that has been done by the general government touching this important subject. Fugitive articles upon the subject have been published here and there in government reports, but they have little permanent value.

State and Territorial governments have done quite as little. Indeed, not one has, so far as we are aware, touched the subject, excepting California. During the past year, this State has had a large engineering force at work, under the supervision of its State engineer, Mr. W. H. Hall, examining the southern half of the great valley, and the valleys of Los Angeles County, on and near the coast, with a direct view to drainage and irrigation. The present extent and character of the irrigation now carried on has been thoroughly canvassed. The nature of the surface of the land as regards

[342] Annual Report Geological Survey of Territories, 1876. Paper on "Arable and Pasture Lands of Colorado," pp. 311-347.

[343] Lands of the arid region.

irrigation has been studied, and all the large streams with most of the minor ones have been gauged at proper intervals throughout the year, giving a fair approximation to the amount of water which may be calculated upon. The work of Mr. Hall forms an admirable basis upon which to commence a well-devised system of irrigation for this area.

As to the total amount of land which can be reclaimed by means of irrigation, but the merest estimates can be made. It is, as was shown above, almost purely a question of the amount of water available. In the first place, we have but few measurements of the capacities of streams; and, except in the case of California, they are but single measurements, and simply represent the state of the stream at the time of gauging. The next day, or the day before, the stream may have carried a very different amount of water. In California, as was stated above, a number of streams have been gauged at short intervals throughout one year. From these measurements with the areas of the drainage basins, it may be possible to make rough estimates of the capacities of the streams of other parts of the country.

But there are other factors entering to complicate the subject. The first, and most important, is the question, What is the "duty" of water, *i. e.*, the amount required to irrigate a unit of land, or the number of acres which one cubic foot per second, throughout the season, can serve? This is not a fixed quantity, but differs with different crops, with different soils, and a variety of other circumstances. Corn requires less water than almost any other crop, while oats and grass require the most. Clayey lands need less than sandy soils, for very obvious reasons. Very level land requires more water than sloping land, as it absorbs more while under irrigation. Crops which are sown broadcast, like wheat or oats, require more water than those planted in drills, as the more expensive mode of flooding must be resorted to for irrigating them. Early sown or planted crops require less water than those planted late, as there is more rainfall in the early part of the season, and evaporation is not as rapid. Land that has been irrigated requires less water than new land. The reason probably is that the soil and subsoil become thoroughly soaked in time. Some even go so far as to say that a piece of land, after being irrigated for a number of years, requires no further watering. It is possible that this may be true for a season or two, but as soon as the water disappears from the subsoil, irrigation will again be necessary.

Major Powell, in his able report on "Lands of the Arid Region," states that the practice in Utah allows from 80 to 100 acres to the cubic foot per second, which is as high a duty as would be expected in Utah, where irrigation is not carried on intelligently or economically. In the San Joaquin Valley, of California, where irrigation is carried on by Americans, and where there is an abundance of water, we naturally find a very low duty, ranging from 50 to 150 acres per second-foot. In the counties of Los Angeles and San Bernardino, however, where most of the ranchmen are Mexicans, who have practiced irrigation for centuries, and where there is a great scarcity of water, nearly all the streams and springs being used up to their full capacity, we find the duty ranging from 300 to 1,500 acres per second-foot. To account for this difference between two sections of the State, Mr. Hall writes as follows: "The explanation undoubtedly lies in the greater experience acquired by the irrigating communities of Los Angeles and San Bernardino Counties, where the art has been practiced longer than in other parts of the State, resulting in the acquirement of more skill in the use of water; in the measures which nature has compelled the irrigators to take for the conservation and economical distribution of water, and to some extent to the character of the crops produced, * * * and last, though by no means least, we find in Los Angeles and San Bernardino Counties better irrigation organizations than in the San Joaquin Valley, which tends to harmonize interests and prevent waste."

A few statistics from the practice in foreign countries will be instructive in this connection. In Algeria the average duty for cereals is reported as 420 acres per second-foot. In the sub-Himalayan districts of India, the practice is to allow one second-foot for 218 acres. In Granada cereals and vines are irrigated at the rate of 240 acres

per second-foot; in Valencia, above 200 acres per second-foot, and in Elche, where water is very scarce, a second-foot is made to do duty for 1,000 acres. Of course such crops as rice require much more water, giving a very low duty.

Hon. G. P. Marsh, in his well-known work, "Man and Nature," after discussing this question thoroughly, comes to the conclusion that 200 acres to the second-foot is a safe allowance. The United States commissioners, referred to above, who made an examination of the great valley of California, came to a similar conclusion. Mr. W. H. Hall, State engineer of California, concludes by saying that this duty, at least, can be reached. Indeed, it seems to be a generally accepted conclusion, that, with the average of crops and soils, and without considering the rainfall, the duty should reach 200 acres per second-foot. In Utah, the practice is, as was above stated, but 80 to 100 acres. In Colorado it is much less, probably 40 or 50 acres.

To arrive at any definite knowledge concerning the amount of arable land in the West, it will be necessary in the cases of nearly all the streams to institute a system of gaugings, to be made at intervals not greater than once a week, to extend throughout the year at least. The simplest way to carry this out would be to have a section made of the river channel at the point selected for the measurements, the section to extend to the marks of the highest floods on the banks. A gauge-rod, suitably placed, and read at the designated times, with measurements of current velocity at the periods of high, medium, and low water, would give data for the computation of the capacity of the stream. Until this is done, we can have but very loose ideas regarding the capacity of our public domain for supporting human life.

As the result of a tolerably careful examination, but not a thorough survey, it has been estimated that, without the use of reservoirs, Colorado contains 7,323 square miles of irrigable land, or 7 per cent. of the area of the State. By storing the surplus water from the spring floods this area can be increased to 10 per cent. at least.

Of the area of Utah, Major Powell estimates that 2.8 per cent. are irrigable without reservoirs. This estimate is based upon an assumed duty of but 100 acres per second-foot. Believing that this duty is but one-half of what can be reached, we are inclined to increase his estimate to nearly double this amount, and to place it at 5 per cent. The use of reservoirs will not greatly increase this amount, as most of the available land can be served by the streams directly. It is probable that not more than 6 per cent. can be irrigated by the employment of reservoirs.

In California it has been shown by survey that practically all of the great valley can be brought under irrigation. Add to this area of 15,000 square miles the numerous valleys of the Coast Range, and of the San Bernardino Mountains, and the total arable area of the arid portion of the State will exceed 20,000 square miles.

Judging from the character and size of the streams and the surface of the country, about 5 per cent. of the area of New Mexico is irrigable, and of Arizona about the same proportion. Wyoming, fully as well watered as Colorado, and having an immense area of plains, should have as great an area of irrigable land in proportion to its size.

Montana has probably very nearly the same proportion, though the great stretch of arid plains in its eastern half would reduce it somewhat. A safe estimate of its arable area would be 8 per cent. Idaho has a slightly smaller proportional area than Montana, but greater than Utah. Probably 7 per cent. is a safe estimate. Nevada has comparatively little water, it is safe to say not more than enough to irrigate 3 per cent. of its area.

Of Oregon, east of the Cascade Range and south of the Blue Mountains, which is the portion requiring irrigation, probably 6 per cent. can be watered. It is claimed that irrigation is unnecessary in any part of Washington Territory. Whether this be true or not, will soon be determined. We are inclined to doubt whether the eastern part can be cultivated, with safety, without water at hand to supply the deficiencies of the heavens.

Of that portion of Dakota lying within the arid region, probably not more than 5

per cent. can be irrigated. Of the arid portions of Nebraska and Kansas, it is difficult to make an estimate, as the rainfall will undoubtedly aid very materially, and the line of the arid region moves from east to west over a considerable distance, from one year to another. If entirely dependent upon irrigation it would be very small, as there are few small streams, and the large ones would be quite fully used in Colorado.

Of Western Texas but a very small proportion can be cultivated, probably not more than 3 per cent., as the whole area of the Staked Plains is irredeemable.

Tabulating the above figures, we arrive at the following results, as the possible arable area of the arid region:

ARABLE LAND.

	Per cent.	Square miles.
Colorado	10	10,450
Utah	6	5,070
California	15	20,000
New Mexico	5	6,060
Arizona	5	5,465
Wyoming	10	9,780
Montana	8	11,500
Idaho	7	6,040
Nevada	3	3,300
Oregon	6	3,000
Dakota	5	5,000
Texas	3	3,750
Total of irrigable land in the arid region	6.4	89,475

That is to say, about one acre in sixteen can be redeemed.

The amount of land at present in actual cultivation in the Western States and Territories is estimated at 8,000,000 of acres. Of this fully one-half is in California, and of this area of 4,000,000 of acres, nine-tenths is cultivated without irrigation, leaving 400,000 acres, or 625 square miles, as the total amount of land in the State under irrigation. The last are the figures for 1879, from the report of the State engineer. Of the remaining 4,000,000 of acres, about 1,000,000 are in the State of Oregon and the Territory of Washington, and of that portion in Oregon nearly all is in the Willamette and other valleys, where the abundant rainfall precludes the necessity of irrigation. There is at present but very little irrigation in this State.

The lands under cultivation in Eastern Dakota, in the Red River Valley, and the valleys of the Missouri, Dakota, Big Sioux, and other streams in the southeastern part of the Territory, may be estimated at 1,000,000 acres more. In this part of Dakota irrigation is not needed. The remaining 2,000,000 acres, or 3,125 square miles, are distributed among the remaining States and Territories in about the following proportion:

	Per cent.
Colorado	30
Utah	20
New Mexico	20
Montana	10
Idaho	6
Nevada	6
Arizona	3
Dakota (arid portion)	2
Wyoming	2
Texas (arid portion)	1

It is unnecessary to say that these are but very rough estimates made in default of any definite information upon the subject.

Out of a possible arable area, then, of nearly 90,000 square miles in the arid region, there is at present an extent of but 3,750 square miles under actual cultivation—a pro-

portional area of but 4.2 per cent. The area yet remaining is equal to that of New York and Pennsylvania combined, or that of Illinois and Indiana. The best of the land and that situated most conveniently to water is included in that already taken up.

A great deal has been said and written upon the subject of irrigation by means of artesian wells, and many hundreds of thousands of dollars have been literally sunken in vain attempts to bring water from the bowels of the earth. It has been a pet idea with many theorists that the great extent of the plains can be fertilized by the promiscuous boring of wells. They seem to have an idea that water is omnipresent beneath the surface, and is only waiting for an opening to be made, to pour itself upwards. They do not reflect that it is only under very peculiar conditions of dip and character of strata, that water having an upward tendency can be found.

If nothing else will stop this senseless clamor for artesian wells surely it would appear that the history of the failures which have attended such attempts should effect it. The Union Pacific Railroad has bored five or six between Fort Steele and Green River City. They are, on the average, about 1,000 feet deep, and cost about $15,000 each. Most of them were at first flowing wells, while in the rest the water rose to within 10 or 15 feet of the top. After a year or two most of them stopped; perhaps two are still running. These were sunken in a locality very favorable for the purpose. The United States Government sunk a well at Fort Russell, Wyo., to a depth of 1,100 feet, at a cost of $10,000, without success. At Denver a well was bored to a depth of 800 feet when the attempt was abandoned. The Kansas Pacific Railroad has also expended a large amount of money in the same fruitless quest.

In Los Angeles and San Bernardino Counties, in California, irrigation by means of artesian wells is carried on to a considerable extent. In this part of the State the soil and climate are exceptionally fine, the crops, very largely fruit and wine-grapes, are very valuable, while water is extremely scarce, and is used with the utmost economy. In these counties there are about 1,000 artesian wells, which irrigate altogether 18,000 acres, an average of 18 acres to each. They are used mainly for small vineyards, gardens, and orchards. Their depth ranges from 40 to 600 feet, while the average is 150 to 200 feet. Success has been had in sinking them only in a few limited localities. Their average cost has been about $400, and the average amount of water brought to the surface by each is about one-tenth of a cubic foot per second. In other words, each second-foot of water has cost $4,000. At the present duty of water in vogue in Colorado, *i. e.*, 40 acres per second-foot, it will be seen that it would cost no less than $100 per acre for a water-right. This is without taking into account the vast amount of money which has been spent in useless borings. Truly, as the State engineer of California says, in concluding his remarks upon this question, "it will be seen that the luxury is a somewhat expensive one." Many people, however, still pin their faith to artesian wells as probable sources of large supplies of water, and scarcely a session of Congress passes without attempts being made to pass legislation looking toward an expenditure of money for boring them. During the last session an appropriation was made for "examining into the needs of the arid region," and for boring two artesian wells "on the plains east of the Rocky Mountains," the appropriation to be at the disposal of the Honorable Commissioner of Agriculture. Fortunately the amount is small, being only $5,000, and it is to be hoped that this amount will serve to demonstrate the utter hopelessness of the scheme. If so, it will not be expended in vain.

There are four general methods of irrigation in use, viz:

1st. Flooding, or downward filtration, by which the surface of the soil is covered with water, which is then allowed to stand and settle into the earth.

2d. Ditching, where the ground is supplied with water from lateral percolation from ditches placed at short intervals.

3d. Subsoil irrigation, where the water is conducted underground and supplies the soil by capillary attraction.

4th. Sprinkling, in imitation of nature's method.

The first method admits of several variations, as follows: If in motion, it may be

in a very shallow layer, applied continuously for a considerable period of time, or in a deep layer for a short period.

If the flooding take the form of a standing sheet of water, it may be quite deep, and be allowed to stand until it all settles into the ground and evaporates. A fourth method is to combine the standing sheet with the flowing one, allowing the water to stand for a short time; then draw it off to some other portion of the field. This process is more applicable to large farms than any other method. It costs less, generally speaking, to prepare land for irrigation by this process, and the work can be done more quickly. But it is applicable only to lands of gentle, even slopes, and a soil which does not cake after being soaked. A large volume of water, comparatively speaking, is required, and there is danger of great waste, unless the irrigator be a man of experience and the ground be well prepared. There are, however, many crops for which this method is not the best.

The second method—by ditching—is also varied, to a considerable extent, in practice. It may be carried, flowing constantly, between the rows of plants, whence it percolates laterally through the intervening soil, or the water may be kept standing in ditches between the rows. In this case the ditches should be larger and further apart than in the previous case. In the case of very open, sandy soils, ditches may be led along the divides, or ridges, at greater or less distances apart, the lateral percolation, or seepage, being sufficient to carry the water over the whole ground.

The ditching method has great advantages over the flooding method in some respects. It costs, in general, very much less to prepare the land and to apply the water. On the other hand, it is ordinarily less economical of water, and requires more time in the application of it.

The third and fourth methods are not, and probably never will be, in use on any considerable scale, for reasons too obvious to mention.

It is impossible to form any estimate whatever of the amount of money at present invested in irrigation works, as there are very few and very scattering statistics on this subject, and it is not a subject upon which inferences can be drawn from the known to the unknown. Still less can any estimate be made of the amount which would be required to construct works which would utilize all the water flowing in the streams and thus bring the maximum of land under cultivation. Such an estimate, even in the roughest form, must await the result of detailed surveys, and the development of definite plans.

During the past few years fertile brains have been busied very extensively in devising ways and means for spending money to no purpose on grand schemes of reservoirs and ditches. These schemes have come from all grades of authority, from an ex-President of the United States, who knew nothing about it, down to a county surveyor, who ought to have known better.

None of the streams of the West carry sufficient water, or command land in sufficient amount, to warrant the construction of any single great work in the form of reservoirs or irrigating canals. The fall of those streams is, almost without exception, sufficiently great to allow the water to be taken up to the bluff lands by a very few miles of ditch. As the primary and almost sole object of a long canal, parallel to the stream is to save fall, so as to command the country, it will be seen that such canals are doubly unnecessary in this region.

When the arable lands of the arid region are developed to the utmost capacity of the streams, they should be distributed in the following general way. Along the base of each mountain range should be a strip of land parallel to the range, more or less continuous, and of greater or less width, in proportion to the amount of water flowing from the mountains. Down each stream of any consequence would follow a belt of cultivated land. If the stream has a rapid fall the belt may be broad, and extend a comparatively short distance down its course. If its current be sluggish, the strip should be narrow, confined, perhaps, to the bottom-lands merely, and may extend down the stream a long distance. The details would depend upon local circumstances.

4. PRESERVATION OF THE FORESTS AND ENCOURAGEMENT TO TREE PLANTING.—Without entering into a discussion as to the value of forests in ameliorating climate, and fully conscious that they must succeed rather than precede such amelioration; in other words, that it is impossible, as a rule, to cultivate forests or extend them successfully in arid regions without first supplying the requisite conditions of moisture; we nevertheless fully appreciate the great importance of preserving as far as possible the timber already sparsely existing in the regions we are considering, and also the desirability of extending it, as a sequence and valuable outgrowth of the increased irrigation we have just been advocating. There are also many sections of the West, especially near the limit line of the distribution of the Locust, where timber growth is spontaneous whenever the prairies are protected from the annual fires which usually sweep over them and hinder forest extension. These facts add weight to all efforts looking either to increased irrigation or judicious restriction and use of fire.

5. JUDICIOUS BURNING.—In this connection we find little occasion to materially modify our views expressed in our first report and repeated on page 272, *ante*. In order not to overestimate the practical benefits that may arise from judicious burning Mr. Thomas has brought together in Chapter II (pp. 16–18) the strongest possible arguments against its practicability, and, after giving these due weight, it yet remains true that in thus burning we have one of the most, if not the most, inexpensive ways of temporarily checking locust increase in many parts of the country where the insect freely breeds. No amount of theoretical objections or of unsatisfactory results, often due to imperfect or injudicious burning, can offset the beneficial results that may be obtained with care and under favorable circumstances. The writer himself has personally witnessed the slaughter of myriads of locusts in this way, and this mode of reducing the numbers of the destructive hordes in their natural habit at once forces itself upon the attention of all who have had experience in that country. The fact that locusts are not destroyed in very great numbers in the Temporary region is due to the fact that the eggs are not laid in this region in the ground covered with dense, long or prairie grasses. The insects would be destroyed by burning were they there. In the more humid prairie country, bare dry spots are preferred for oviposition; but in the Permanent region the insects will abound most where the vegetation is rankest and most succulent. A study of Map I will give an approximate idea of the amount of land in the plains area, the vegetation of which is susceptible of being burned over, and will also show that it includes all the more arable and valuable land for settlement—a fact of great importance.

In the plains area proper there is little or nothing to prevent wholesale burning of the vegetation late in the spring, after the bulk of the locusts have hatched out, beyond the expense of preventing such burning the previous fall. The only practical way in which this could be done

would be by a system of fire-guards where there are no natural streams or other barriers to prevent the spread of the flames. We repeat, that any extensive system of guarding the vegetation in the fall so as to fire it the ensuing spring would only be warranted at government expense in those particular areas where it is absolutely known that eggs have been thickly laid and that the insects from such eggs will swarm the following year. Such a condition will occur only at irregular intervals and the government should take some steps to provide for annual observations that will lead to a knowledge as to when and where such conditions prevail. Systematic firing should then be carried on from the circumference of such area or areas after the bulk of the insects are known to have hatched and before they are able to escape by flight. That such work can profitably be performed in large portions of the permanent region, we have little doubt, and that the expense in such instances would be warranted is made manifest by the terrible losses which the insects are capable of occasioning.

In many sections a system of fire-guards will be absolutely necessary to judiciously carry out any such scheme, in order to prevent the destruction of timber.

6. A PERMANENT SYSTEM OF OBSERVATIONS AND WARNINGS.—In order to carry out the plan just considered, and, in fact, to enable the government to take any intelligent action looking to the direct destruction and decrease of the Locust in the region under consideration, systematic observations made and reported from year to year are absolutely essential, and we cannot too strongly urge upon Congress that provision be made for such continued observations. There is no reason why it should not be made part of the duty of the Signal Bureau to obtain the desired information, and to report the situation to the country from time to time. The source of these destructive insects is no longer an utter mystery, and every year is adding to the facilities for making the desired observations.

With an increasing population; with the near completion of projected roads through Montana and adjoining Territories; with the completion of the Canadian and Northern Pacifics now assured, the means of establishing a system of locust signals and warnings, and of making more complete and accurate observation, will be far greater than they have been. Information as to the situation and extent of egg-deposits; the time of hatching of the young locusts; their movements both on foot and on wing, can and should be as rapidly obtained and disseminated as possible. The local press will be but too ready to disseminate it. The course of flights from day to day should be traced and published in the maps issued and now generally posted at available points, as post-offices, depots, etc. In many instances such warnings would enable the farmer to cut and save his crops before the swarms reached him, that would otherwise, unheralded, swoop down upon him and in a few hours destroy the labor of a year. Tracts which it would pay to guard

against fire in autumn and then burn the ensuing spring, as we have just set forth, could also be mapped out and the maps published for the general good and as guides to Congressional action, while an annual report on the locust condition and prospects, to be made part of the report of the Signal Bureau, could not fail to greatly interest and benefit the people most concerned, and indirectly through them the whole country.

A limited appropriation to the Signal Bureau for this special purpose, that would enable the Chief Signal Officer to begin at once the work here suggested, under the direction of some competent person or persons, would, we have no doubt, directly tend to immensely increase the practical usefulness of the bureau to the farming community dwelling in the vast regions subject to locust injury. Even the observations of the individual commissioners and their agents, limited as they have necessarily been as compared with those which the Signal Bureau could make, have been of great service in permitting, since its organization, annual statements and prognostications that have proved correct to a remarkable degree; while, in the event of a repetition of the scenes of 1873 to 1877, no one would question the value of daily bulletins, such as the Signal Bureau might publish with the increased power we have indicated, as to the movements and flights of destructive swarms. We therefore strongly recommend an appropriation to the Signal Bureau for this special purpose.

7. CO-OPERATION WITH THE DOMINION GOVERNMENT.—That efforts in any schemes for the protection of the western farmer from locust injury should be made as far as possible with the co-operation of the Dominion Government is too apparent from the facts presented in this and our previous report to need any special emphasis or argument.

PREVENTIVE MEASURES IN THE MOUNTAIN AND PLATEAU AREAS.

The measures to be adopted to prevent locust injury in the more mountainous area must be essentially the same as those we have recommended on the plains; but, as shown in Chapter II (p. 24), there is in the intermontane area less land adapted to agricultural pursuits than in the plains area, and the chief industry in the former section will always be that of mining. Dr. Packard, who has more particularly studied the problem in the mountain and plateau areas, gives the following report of his views and experience as to the best means of counteracting and lessening the injury in the mountains:

"The arable lands are the bottom lands among the Rocky Mountains, the Uintah and Wahsatch Ranges, which lie for the most part between the altitudes of about 4,000 and 8,000 feet. Above this height, owing to summer frosts and cold nights, as well as cold storms, the locusts do not flourish in great numbers nor arrive at maturity until two or three weeks after those which have hatched out in the regions below have become fledged and flown away.

"It is evident then that the breeding grounds of the locust are in those

regions of the Rocky Mountains which will ultimately be taken up by settlers as farming and grazing lands; hence, when this region is settled, the prevention of locust injuries will be a problem much easier of solution than at present.

"The effect of putting this large area under more or less thorough cultivation, either as irrigated farms or cattle and sheep ranges, will be to render the country less liable to great and prolonged drought, and thus cause the climate to be more equable. All this will tend ultimately to keep the locust within its normal limits, so that it will not in certain favorable years multiply to so great an extent as to lead to extensive migrations into adjoining or remote regions. The locusts will be restrained within their natural and original limits. Hence the best means of protection will be to destroy the eggs and to fight the young when they hatch, and to exterminate them by all the methods fully described in the First Report of the Commission. The greater the number of eggs and young destroyed within the Permanent Region year after year, over a period of 25 or 50 years, the more will the number of individuals throughout the whole area be lessened.

"The settlement of Montana and the western border of Dakota will ultimately have a great effect in lessening the extent of the breeding grounds of the locust; and thus diminish the numbers of those which swarm into Utah on the one hand, and Minnesota, Iowa, and Nebraska on the other.

"The State of Colorado is invaded by swarms which originate west of the range about the White and Bear Rivers, and north and northwest from the Wind River Valley and the Laramie plains of Wyoming, so that these regions are the tracts which need to be occupied, and where an unremitting warfare, pursued with combined effort year after year by the farmers, will ultimately tend to keep the locust within comparatively harmless bounds.

"To this end the replanting of the forests, now being recklessly cut down by the settlers of the Western Territories, will have a favorable effect, both tending to reduce the extremes in the seasons, and to break up and diminish the breeding grounds of the locust. Moreover, the construction of railroads and the settlements which spring up along them will have their effect in reducing the extent of the breeding grounds.

"The settlement also of the wild lands of the Rocky Mountain plateau will in a measure tend to keep the locusts from migrating eastward. If there were a sufficiency of food in the plateau region, there would be no inducement for them to take flight for regions situated five hundred to a thousand miles eastward, for without much doubt the main cause of their migration is the desire for food; for if the broad, extended plains of the region between the mountains and the Mississippi Basin do not afford them sufficient food, they will pass on to the prairie region of the western edge of the Mississippi Basin.

"While, therefore, we do not see how any special means of extermi-

nating the native locust in the Rocky Mountain region can be systematically and extensively applied beyond locally burning over tracts and destroying the freshly-hatched young, we may with confidence predict that even in ten or twenty years from now, when the rich grazing and farming territory of Montana will sustain a much denser population than at present, the locusts may be in many places locally exterminated, their numbers in general diminished, and their ravages be greatly lessened.

"As is well known, the greater part of the injury done by the locusts is accomplished by the voracious young working in fields of young wheat. The winged adults swarm in after the wheat is harvested or about the time of harvest.

"What the farmer of Colorado and Utah wants in the middle and latter part of July is certain, reliable, and detailed information respecting the presence or absence of locusts west of the Rocky Mountain Range or in Wyoming northward, if he live in Colorado; or, if he be a Mormon farmer, whether the locusts are flying from Montana into the region of Idaho lying north of Cache or Malade Valleys. He may then be able to tell whether to expect the locusts late in August or early in the autumn in his own country. At the present time the western border farmers pick up in a desultory and haphazard way information of this sort, but as the Far West becomes more densely populated and increased care and diligence are observed, as they will have to be exercised in the future when the struggle for existence becomes more intense among agriculturists and wheat-growers, all the means we have referred to of obtaining, classifying, and disseminating a knowledge of the movements of the locusts will be more or less fully adopted. When this result is attained the battle with the locusts is more than half won. A tolerably complete knowledge of the habits and movements, direction and time of flight, &c., over a series of years will also (as it already has in Utah) tend to clear up the mystery hitherto attending the migrations and ravages of locusts. This will have the effect of making the agricultural community less subject to wild panics, and more bold, determined, and combined in endeavoring to exterminate the locusts.

"A large proportion of the money losses resulting from the locust invasions of 1867, '69, '74, and '76 was the result of a panic, of uncertainty as to the future; this resulted in disheartenment, in the abandonment of large tracts of the best of farming lands to nature and the locusts. This will probably never again happen in the West. The knowledge already disseminated, the extent of the population now pouring into the Northwest, the rapid settlement of the Territory of Montana, and the completion of the Northern Pacific, Canadian Pacific, the Utah and Northern Railroads, and the consequent change in the surface of the country due to human agency will so essentially modify the locust situation that we believe the West will never again suffer as in the past. It remains for the people of the Rocky Mountain Plateau to use such local and general

means as their own experience and this Commission have suggest
the first and present reports; for the State and Territorial and c
governments to make and execute laws for combined and persi
action during times of general local invasion and for the preventi
others. If this be done in the plateau region in the future the inva
of the western border Mississippi States will tend to become more
more feeble, inconsiderable, and harmless, until, we venture to pre
the time will come when the losses from locusts will be only local
comparable with those inflicted by locusts and grasshoppers in the e
ern Atlantic States. At any rate, the western locust has already ce
to be a bugbear and object of dread; familiarity with its habits
history has already taught the pioneer farmers of Utah, Montana,
Colorado that with energy its ravages can be lessened if not entir
overcome, and no one intending to migrate west from the Atlan
States or from Europe need to be deterred by the fear of such alarmi
invasions as have occurred in former years."

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