U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF FORESTRY—BULLETIN No. 44.

GIFFORD PINCHOT, Forester.

THE DIMINISHED FLOW OF THE ROCK RIVER IN WISCONSIN AND ILLINOIS,

AND

ITS RELATION TO THE SURROUNDING FORESTS.

BY

G. FREDERICK SCHWARZ,

Field Assistant, Bureau of Forestry.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

BUREAU OF FORESTRY.

GIFFORD PINCHOT, *Forester.*

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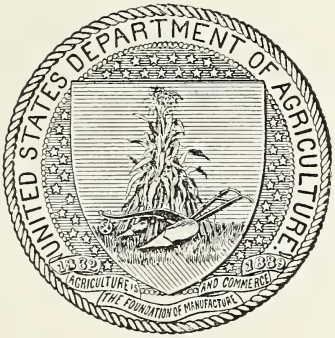

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Forestry,
Washington, D. C., June 27, 1903.

Sir: I have the honor to transmit herewith a report entitled "The Diminished Flow of the Rock River in Wisconsin and Illinois, and its Relation to the Surrounding Forests," by G. Frederick Schwarz, Field Assistant in the Bureau of Forestry, and to recommend its publication as Bulletin No. 44 of the Bureau of Forestry.

The four plates and two maps accompanying this bulletin are necessary for its proper illustration.

Very respectfully,

Gifford Pinchot, *Forester.*

Hon. James Wilson,
Secretary of Agriculture.

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THE DIMINISHED FLOW OF THE ROCK RIVER IN WISCONSIN AND ILLINOIS AND ITS RELATION TO THE SURROUNDING FORESTS.

INTRODUCTION.

The purpose of the investigation the results of which are here presented was to ascertain the principal factors upon which the flow of the Rock River depends, to determine the relative importance of each, and, if possible, to discover any practicable means of increasing the flow or equalizing the volume of the river. The study includes a consideration of the geology of the region, the recent fluctuations in the rainfall, the effects of the artificial drainage of swamps and fields, and the manner in which forests influence the water flow, and aims not only to explain the decreased water flow in the Rock River region, but also to throw light on the relation of forests to water supply in general.

The local impression is that for some years past the Rock River has been decreasing in volume, or at least changing in the regularity of its flow. In summer the upper tributaries and smaller creeks have occasionally run dry. Should these changes continue, they would interfere with various industrial interests of the region. Numerous mills and other manufacturing plants in the towns along the river depend upon its water power. There are also dams and locks for slack-water navigation at the principal cities. A canal that extends across the State of Illinois from the lower end of the Rock River to the Illinois River draws upon the Rock River for a part of its water supply. Moreover, the agricultural interests of southeastern Wisconsin, including extensive cultivated and pasture lands situated among the numerous headwaters and smaller tributaries of the Rock River, rely to some extent upon these sources for sustained moisture in the soil, particularly during seasons of irregular or diminished rainfall. These various industries—manufactures, transportation, and agriculture—are closely dependent upon a steady water supply, and therefore upon the forest, which is an agency of the first importance to this end.

Besides their importance as an agency in regulating the water flow, the forests of the Wisconsin watershed add to the attractiveness of the region, which is annually visited by many people because of its beautiful scenery and the excellent fishing and shooting it affords.

While the changes thus far observed in the flow of the Rock River appear not to have been so great as to cause serious apprehension, the interests affected are sufficiently important to give to the question of the conditions on which the river flow depends and the possible means of preventing further decrease a decided local significance. It was in consequence of an expressed desire on the part of citizens of the parts of Wisconsin and Illinois involved that the investigation of this question was originally undertaken by the Bureau of Forestry.

The special problem in stream flow presented by the Rock River watershed is rather simple in character, and the main facts can be compassed in a brief report. But in view of the general interest that attaches to the subject of water flow, that part of the report dealing with the influence of the forest cover has been extended so as to include certain suggestive results of recent observations made in Europe. In the light of the facts thus established it is also possible to draw more definite conclusions than could be arrived at by any study of local conditions which it was practicable to make.

The writer wishes to express his obligations to the following gentlemen who have rendered assistance in this investigation: The Hon. R. R. Hitt, Representative in Congress for the Ninth district of Illinois, at whose request the investigation was undertaken; Prof. Thomas C. Chamberlin, of the University of Chicago, and Prof. C. R. Van Hise and Mr. C. K. Leith, of the University of Wisconsin.

SUMMARY.

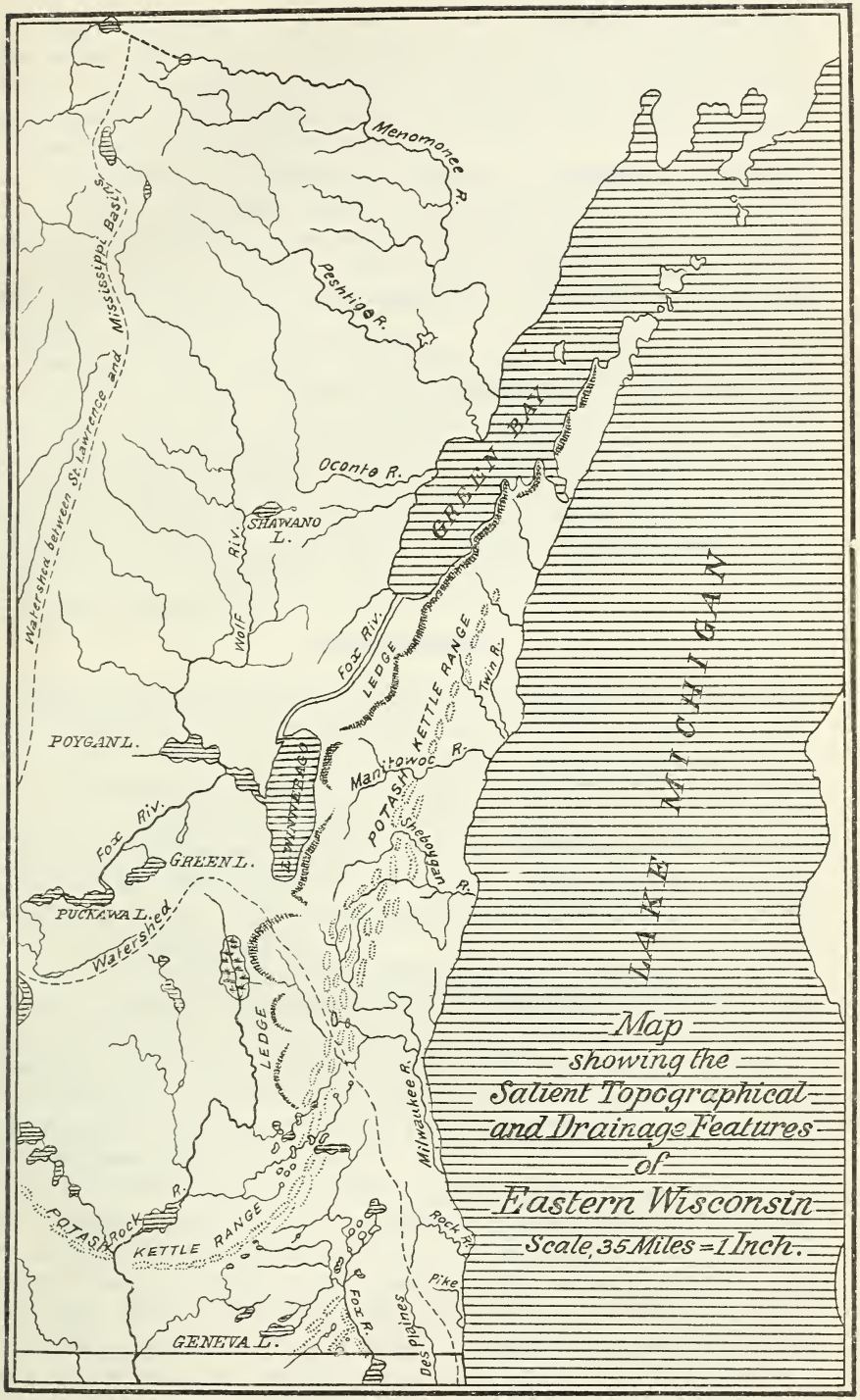
The results of this study may be summarized as follows:

The geological formation and topography of the Rock River watershed are favorable to a sustained water supply.

Since the settlement of the region the forests have been much reduced in area, while the conditions of growth in those that remain have changed for the worse. Cultivated land and woodlots have been largely converted to pasturage, thus interfering with the waterflow. In some districts the swamps and fields have been artificially drained.

Since 1885 the rainfall has decreased. This loss has probably lessened slightly the *volume* of the river flow. The *fluctuations* in the flow, however, have been caused by artificial drainage and by changes in the forest conditions of the region. Of these the latter is probably the more important cause.

Forests diminish the loss of water by evaporation from the ground. At Nancy, France, it has been found that in the summer months five times as much water is evaporated outside of the forest as within it. Against this must be set off the slight loss of water which is intercepted in falling by the leaves of the trees and evaporated without ever reaching the ground, and the consumption of water by the trees


Menomonee R.
Peshtigo R.
Oconto R.
SHAWANO L.
Wolf Riv.
Fox Riv.
LEDGE
KETTLE RANGE
Twin R.
GREEN BAY
LAKE MICHIGAN
Watershed between St. Lawrence and Mississippi Basins
POYGAN L.
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GENEVA L.
Des Plaines
Map
showing the
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and Drainage Features
of
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for their own needs. It is doubtful, however, whether the loss from the latter cause is not greater in the case of field crops than in the forest. On the whole, it is safe to say that a larger proportion of the precipitation gets ultimately into the streams from a forest-covered region than from one that is unforested.

Forests exert a very important influence in equalizing the stream flow. Snow melts more slowly in the woods than on open ground, and the water-holding capacity of forest soil retards the run-off of both rain and snow water. The reduction which has taken place in the area of forested land in the Rock River region has therefore had an unfavorable effect on the streams.

That part of the original forest which still remains has undergone a change in character. Cutting and pasturing have produced an open growth. One result of this is greater evaporation. Another result is a deterioration in the character of the soil and a consequent loss of moisture-holding capacity. Grass and weeds have entered, and the absorption of moisture by a growing soil cover has thus been increased. Changes in stream flow have therefore resulted from the changed conditions of the forest which remains, as well as from the loss of that which has disappeared.

CONCLUSIONS.

Improvement in the flow of the Rock River depends on the practicability of storing the water which falls in rain and snow so that it may be discharged in an even and constant volume. One possible method of accomplishing this is through the agency of artificial reservoirs. The question is whether the pecuniary benefit which would be gained would be great enough to pay for the land which would have to be acquired and the dams which would have to be built. This is for the interests affected to decide. It is a purely private and business question, which need not be discussed here.

Another possible method of equalizing the flow is through the agency of forest growth. The present condition is largely the result of forest destruction and forest deterioration incidental to the agricultural development of the region. In this case, therefore, the question becomes, Can it be shown to landowners in this region that it would pay them individually to have a larger part of their farms timbered, or to improve the character of their woodland?

It is believed that the present condition of the average woodlot in this region is such that the owners are now suffering an actual loss of a considerable part of their value, and that the area now wooded might often be extended with a resulting clear profit to the farm. It is further believed that this added return may be secured by anyone of ordinary intelligence and enterprise, without expert assistance and without the outlay of capital or any expenditure other than that of a

little time and forethought. It is in order to show this to practical farmers that the latter part of this report has been prepared, and it is earnestly hoped that it will receive the careful attention of those who are interested in bettering themselves, but have not as yet given much thought to the possibilities of the woodlot, which is, after all, so important a part of a good farm.

EXTENT AND TOPOGRAPHY OF THE ROCK RIVER WATERSHED.

The headwaters of the Rock River are situated at the lower end of a depression that extends from Green Bay and Lake Winnebago southwestward toward the southern boundary of Wisconsin. (Pl. I.) Near that boundary the valley is interrupted by the glacial drift of a moraine, known as the "Potash Kettle" or "Pots and Kettle Range." Throughout a part of this extent this range forms the eastern boundary of the upper drainage basin of the Rock River. A series of ledges and cliffs extend along the western side of the Kettle Range, and overlook the extreme northern sources of the river. The drainage basin itself is confined on the northern side by a watershed that separates the St. Lawrence from the Mississippi River Basin, and divides the depression of southeastern Wisconsin into an upper and a lower section.

The greatest length of the Rock River Basin in Wisconsin is 85, and its greatest breadth 65 miles. The area of the basin is 3,635 square miles,[a] and is included almost entirely within five counties. The surface is moderately hilly; it varies in elevation from 750 feet where the river enters the State of Illinois, to 1,100 feet on the crests of the Kettle Range. The rise from the interior of the valley is gradual, and usually the hilltops are not more than 100 feet above the intervening valleys, with an average slope of about 3 degrees. This low, uneven topography has led to the formation of an intricate tributary system (Pl. II), with numerous spring-fed lakes, which, under ordinary circumstances, furnish excellent means for an ample water supply. (Pl. III, figs. 1 and 2.)

The fall of the river from Horicon Marsh, at the north, to the city of Beloit, at the Wisconsin State line, is only 135 feet. This moderate descent continues until the Mississippi is reached at an altitude of 540 feet, or 210 feet below that of Beloit. An account of this lower part of the Rock River is omitted for the reason that its tributary system is comparatively insignificant.

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[a] Geology of Wisconsin, Vol. II, p. 171.

GEOLOGY OF WISCONSIN AND OF THE UPPER DRAINAGE BASIN OF THE ROCK RIVER.

The geology of this region has a direct bearing upon the water flow, and should be briefly considered before discussing the other factors connected with this problem.

The following epochs are represented in the geologic formations of Wisconsin:

Pre-Cambrian		An unseparated complex of crystalline rock.
Paleozoic	Cambrian	Potsdam sandstone.
	Lower Silurian	Lower magnesian limestone.
		St. Peter sandstone.
		Trenton limestone.
		Galena limestone.
		Cincinnati shales and limestone.
	Upper Silurian	Niagara limestone.
	Devonian	Hamilton limestone.

The pre-Cambrian is represented by intricately folded ancient crystalline rocks, forming the base upon which the later rocks, belonging to the Paleozoic, rest unconformably and comparatively undisturbed from the base upward in the order named. A subsequent slight tilting of the entire series toward the south, followed by a cutting away of the upper surfaces, has resulted in the exposure in successive zones of the various kinds of rock represented. The oldest is found in the northern part of the State; the more recent deposits to the southeast, south, and southwest. They have since been covered in great part by the drift and morainic débris of glacial times.

The alternation of layers of rock of different composition and the variations of structure found within some of these separate formations facilitate the drainage. The geological dip also contributes to this result. It slopes to the southeast and, on the average, is not over 5 feet to the mile; yet this is sufficient to convey some of the percolating waters from the north down to the southeastern part of the State, where they reappear as springs to feed the glacial lakes of this region.

The principal source of the water supply within the Rock River drainage basin is the precipitation, and the economy of its distribution depends largely upon the character of the surface upon which it falls. The topography, as already noted, presents no prominent features. The soil conditions vary on different parts of the watershed, according to the exposures of the different layers of rock. In the west and northwest the headwaters of the river spread over the Potsdam sandstone, the lower magnesian, St. Peter sandstone, and Trenton limestone, and over the glacial drift that has covered these deposits. The main part of the drainage, however, lies over the area of the Galena and Niagara limestones and the Cincinnati shales.

The glacial drift on the surface allows a very free percolation of the water. The sandstones underneath are also fairly pervious, while the limestones and shales offer no serious obstruction. The geologic conditions, therefore, may be said to be very favorable to a sustained and ample flow of the river.

EXTENT AND CHARACTER OF THE ORIGINAL AND THE PRESENT FORESTS OF THE WISCONSIN DRAINAGE BASIN.

This region at the time of its first settlement some sixty years ago was extensively covered with forests, which, like those now standing, were composed chiefly of hardwood species, including the Bur, Black, Red, and White oaks, Basswood, Hard Maple, hickories, elms, and ashes. On swampy ground grew Tamarack, White Cedar, spruce, and willow. (Pl. IV, figs. 1 and 2.) The total area of the forest at that period may be estimated conservatively at 75 per cent. Allowing 5 per cent for water surface, this would leave 20 per cent to be divided about equally between prairie land and the low, marshy meadows bordering the creeks and small streams.

Since the settlement of the region some marked changes in the soil cover have taken place. A large part of the forest has been removed and the land brought under cultivation. Most of the prairie lands have also been converted to agriculture, and many swamps and sloughs have been drained and tilled. A considerable part of the 10 per cent of marsh land, however, still remains. The proportion of land types and water surface is estimated as follows:

	Per cent.
Forest	30
Cultivated land	57
Swamps and uncultivated meadows	8
Water surface	5

In some sections—as, for instance, in the western part of Dane County—the proportion of forests has increased since the time of settlement; in others it has materially diminished. This diminution is not always noticeable, because narrow strips and small wedges of tree growth sometimes obstruct the view across the low, undulating country and hide the extensive fields beyond, thus making the land appear more heavily wooded than it is.

Not only have the wooded areas diminished, but significant changes have taken place in the conditions of growth. Originally the forests contained a natural undergrowth of herbs, moss, tree seedlings, and shrubs, which preserved the moisture and aided in the formation of a rich, receptive mold. Some of the forests still retain this natural surface growth, but many of the farm woods have been given over to pasturage and have run to a dense matting of grass.

CAUSES THAT HAVE INFLUENCED THE FLOW OF THE RIVER.

THE RAINFALL.

The most obvious explanation for the smaller amount of water annually carried by the Rock River is the diminution of the rainfall. This will appear from the following table, which embraces the drainage basin in Wisconsin:

Table of precipitation, in inches, for the years 1885 to 1900, inclusive.[a]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.	Total for 4-year periods.
1885...	1.8	0.8	0.4	3.2	1.2	5.9	4.8	7.7	4.0	2.7	1.0	2.9	36.4	
1886...	4.1	1.6	4.2	2.9	2.4	2.2	1.0	4.5	2.2	2.4	1.3	1.5	30.3	
1887...	2.8	4.2	1.6	1.0	1.6	.9	4.1	5.0	5.0	2.7	1.2	4.1	34.2	1885–1888, 129.3.
1888...	1.4	1.1	2.1	2.3	3.9	3.4	4.0	2.5	1.5	1.9	1.8	2.5	28.4	
1889...	1.9	2.5	1.3	2.2	4.3	4.7	2.9	1.0	2.2	.3	2.0	2.5	27.8	
1890...	2.4	1.9	2.1	3.1	4.1	7.1	1.2	3.1	1.4	4.4	2.1	1.0	33.9	
1891...	1.6	1.3	2.5	3.2	1.5	4.1	2.9	1.7	.3	1.8	3.1	2.2	25.2	1889–1892, 124.0.
1892...	2.4	1.7	1.6	3.2	7.5	7.9	2.4	3.1	2.5	1.5	1.5	1.8	37.1	
1893...	1.5	1.4	2.6	5.1	2.0	3.9	3.2	1.5	2.7	2.4	1.3	2.3	29.9	
1894...	1.6	.8	2.4	3.4	4.0	3.6	1.2	.9	5.8	2.2	2.4	.8	29.1	
1895...	1.6	.6	.8	1.2	4.0	2.0	2.4	3.2	1.8	.5	2.3	2.0	22.4	1893–1896, 113.1.
1896...	.9	.8	1.6	4.2	4.9	2.6	4.3	2.2	6.4	1.1	2.0	.7	31.7	
1897...	2.9	1.3	3.2	4.0	1.0	4.7	2.8	2.8	1.5	1.1	1.5	1.7	28.5	
1898...	2.3	2.0	3.2	2.1	3.0	4.8	3.1	3.8	2.3	3.9	1.2	.5	32.2	1897–1900, 119.5.
1899...	.6	.7	1.5	1.9	5.1	3.4	3.1	2.8	3.0	1.7	1.7	1.7	27.2	
1900...	1.5	2.3	1.6	2.5	1.9	1.9	6.7	4.0	2.7	3.6	2.3	.6	31.6	
1901[b]...	1.1	1.2	2.8	.5	2.4	1.8	2.7	1.0	3.2	1.8	.8	1.3	20.6	1901–1902, 56.1 (=112.2[c]).
1902[b]...	.4	1.5	1.2	1.2	6.3	4.9	9.2	.8	4.2	1.4	2.3	2.1	35.5	
Average[d]	2.0	1.6	2.0	2.8	3.3	3.9	3.1	3.1	2.8	2.1	1.8	1.8	30.4	

[a] Compiled from data furnished by the United States Weather Bureau.
[b] The figures for 1901 and 1902 are based upon a more restricted area than the figures for 1885 to 1900.
[c] Approximated for a period of four years.
[d] For the period 1885–1900.

The most significant figures are those for the years 1893, 1894, and 1895, when the annual precipitation averaged only 27.1 inches, or 3.3 inches below the average for the entire period, from 1885 to 1900, for which complete records of precipitation are available. The monthly precipitations during these three years were also very irregular, although it can not be said that the deficiency was any greater during the summer, when the rain is most needed, than during other seasons. The departure from the normal during the period from 1893 to 1895 was preceded by the heavy precipitation of 1892, but this precipitation was needed to replenish the supply after the severe drought of 1891; and the same is true in 1890, as well as in the alternate years since 1895. If the eighteen years be divided into four and a half 4-year periods, it will be seen from the column at the right that, with the

exception of a slight return to normal conditions in the fourth period, there has been a decrease in precipitation from 1885 to the present time.

The foregoing facts, though they do not determine to what extent the diminished precipitation has affected the flow of the river—since corresponding figures for temperature, evaporation, and wind velocity are wanting—nevertheless suggest one of the obvious reasons for the change. In attempting to weigh the importance of this factor it should be remembered that the greatest fall from the average of 30.4 inches for any three consecutive years was 3.3 inches. This does not appear to be a very serious loss, considering the conservative tendency of the geology of this region. The table shows, moreover, that the months from April to September, inclusive, when water is most needed to sustain the flow, have decidedly the heaviest precipitation.

Admitting, therefore, that a diminished rainfall may have influenced to some extent the volume of the river flow, the disturbance in the regulation of that flow must be ascribed to other causes. Where the average annual rainfall is just sufficient for the ordinary purposes of agriculture and the industries, as in the present instance, the distribution of the supply becomes important. In order that a sustained flow of water may be secured, the spring rains and the melting snow should be economized for later distribution. The combined supply from these two sources is considerable. Where it is allowed to penetrate into the earth and thus find its way gradually to the streams, it constitutes a safeguard against the urgent needs of the warmer season, during which heavy intermittent showers produce a more rapid run-off, not infrequently followed by periods of drought and intense evaporation.

This disturbance in the regulation of the water flow of the Rock River must be ascribed partly to the artificial drainage of cultivated areas, but chiefly to the changes that have taken place in the soil cover since the time of settlement.

ARTIFICIAL DRAINAGE.

The custom of laying tiles and other drains and of cutting ditches to improve the condition of the fields prevails throughout this region, and has resulted in a more rapid delivery of the rain water into the streams. Many of the swamps and sloughs that formerly helped to feed the smaller creeks and tributaries have likewise been drained to bring their rich soil under cultivation.

The case of the Horicon Marsh deserves to be specially noted as an example of drainage. The history of the changes that have taken place on this marsh also points to the possibility of an improvement in the water supply by a system of storage. The tract is situated at the northern end of the river, and is, in fact, its first source (Pl. II). As early as 1846 the marsh was converted into a lake for water-power

purposes by the construction of a dam at its southern end. Afterwards, from a belief that the land at the bottom of the lake would prove exceptionally valuable for agricultural purposes, the dam was removed and the tract allowed to revert to its original condition, but apparently without fulfilling the expectations which had been entertained. At present the prevailing opinion seems to be that it would be wise to reconstruct the dam in order to help the regulation of the flow of the river during the critical months of July, August, and September. As the old lake covered an area of 73 square miles, and its catchment amounted to approximately 400 square miles, which is very nearly one-ninth of the entire Wisconsin drainage area of the river, it appears likely that the husbanding of the spring freshets at Horicon Marsh by means of a dam would overcome to some extent a scarcity in the summer months.

EFFECTS OF CHANGES IN THE SOIL COVER

The other factor which has affected the rate of the water flow, the soil cover, is probably much more important than the influence of artificial drainage. Under this head the forest changes hold the first place. The importance of these changes lies not, as is often supposed, in the influence that forests may possibly have upon rainfall, but in the fact that they have a decided effect upon both the evaporation and the distribution of the rain after it has fallen. In the region here considered the reduction in the area of the forests has probably not resulted in any appreciable decrease of the rainfall. Such a change may possibly have taken place to the north and in the neighboring States of Minnesota and Michigan, where large and continuous forest areas have been enormously depleted within the past three decades; and it is conceivable that the extensive alteration of these regions may, notwithstanding their remoteness, have had some slight influence on the diminished rainfall shown in the table on page 13. The relation between forests and rainfall, however, has not been sufficiently investigated to draw positive conclusions for particular localities. On the other hand, the effects of a forest cover on evaporation and distribution have been successfully studied, and are of interest in the present discussion because a retarded evaporation from soil would naturally increase the available water supply, while a regulated distribution of that supply would increase its effectiveness.

INFLUENCE OF THE FOREST ON EVAPORATION.

Investigations carried on for a number of years in different parts of Europe have proved that the humidity within a forest is greater than over open ground, while the temperature is lower during the summer months both within the forest itself and in its soil. These

conditions, as well as the protection afforded by the leafy canopy against the rays of the sun, materially retard evaporation. It should be remembered, also, that the forest protects the soil from the drying action of the winds, which in open areas constantly absorb the moisture from the surface. As evaporation increases very rapidly with an increase in the velocity of the wind, the opposition offered by the forest is a means of protection of the first importance.

A very instructive study of soil evaporation within and without the forest has been carried on at the experiment station connected with the national forest school of France. The results of thirty-three years of observation, recently published,[a] are thus summarized:

> It appears, therefore, that during the months of November, March, and April, for which complete data are available, the instrument situated on open ground has always lost about twice as much water as the one situated within the forest. * * * During the summer the difference is much more striking, owing to the presence of foliage, and varies considerably, being very decided as the temperature rises. The proportionate amounts evaporated outside and within the forest are as 3 to 1 in May, 5 to 1 in June, July, and August, 4 to 1 in September, and 3 to 1 in October.[b]

In winter and early spring the forest is useful in preserving the snow cover, which furnishes a considerable part of the water supply of the ensuing season. This preservative influence is less in deciduous forests than in such as are composed of evergreen species; nevertheless, the trunks and branches of the trees and the dried foliage retained by oaks and several other species during a part of the winter protect the snow to a certain degree from the sun and wind. The leaf litter on the forest floor is also of some value, because snow that falls on it does not melt as readily as on bare soil. Scientific investigations have shown a decided difference in the preservation of snow on forested as compared with unforested areas, resulting in a more uniform and sustained flow of the streams where forests are present.[c]

To appreciate the influence of a forest cover in all its aspects, the amount of moisture required for the growth of the forest itself should be taken into consideration; and the fact should also be noted that the crown cover of a forest intercepts some of the precipitation, which, therefore, never reaches the soil. The loss occasioned by the intervention of the crown cover, however, is not excessive, and may be offset in part by the effect that the saturated foliage probably has in retarding evaporation from the soil. Some idea of the loss due to the presence of the crown cover may be obtained from the results of studies carried on in a deciduous forest situated on a plateau to the

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[a] Observations de Météorologie Forestiere. M. Raoul de Drouin de Bouville.

[b] The months of December, January, and February were not included in the summary, because the results for these months were unreliable on account of frequent frosts.

[c] See also Forests and Snow, by L. G. Carpenter. Colorado Agricultural Experiment Station Bulletin 55, 1901.

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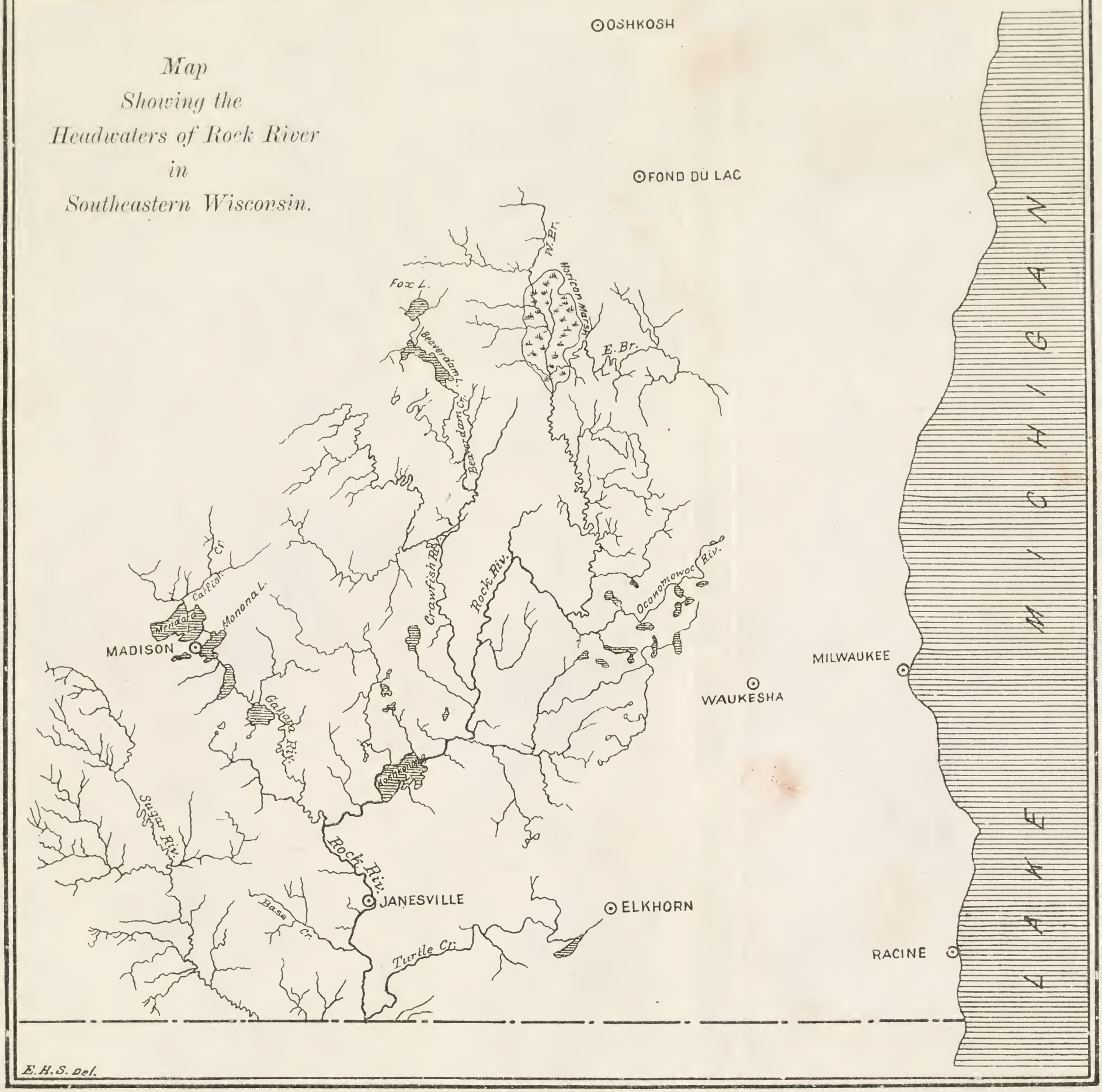
E.H.S. Del.

Map
Showing the
Headwaters of Rock River
in
Southeastern Wisconsin.



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west of the city of Nancy, France, which are summarized in the following extract taken from a table in the publication referred to on page 16:

Difference in precipitation under forest cover and in a clearing within the forest. [a]

Period, 1867 to 1898.	May to October.		November to April.		Entire year.	
	Within the clearing.	Within the forest.	Within the clearing.	Within the forest.	Within the clearing.	Within the forest.
Average seasonal and annual precipitation, in millimeters	474.8	421.7	372.1	360.4	949.9	782.1
Percentage of precipitation within the forest as compared to that within the clearing	88.8		96.9		92.4	

[a] The observations were conducted in a deciduous forest, situated on a slight uplift or plateau to the west of the city of Nancy, France.

The other element of loss, namely, the amount of water consumed and transpired by the trees, has been repeatedly investigated, but the subject is extremely complicated. The consumption varies with the kind of soil and its physical condition, with the amount of the rainfall, with the condition of the atmosphere, and, in still greater measure, with the species of tree and character of forest. The figures resulting from these investigations consequently show very wide limits, and it still remains somewhat doubtful whether forests, as compared with field crops, require more water for their growth, or less. [b]

INFLUENCE OF THE FOREST ON WATER DISTRIBUTION.

It is well known that forests also economize the distribution of rain water. The constantly decaying mold and the litter of freshly fallen

[b] A table by Risler, which has been frequently quoted, is here reproduced from Vol. III of the Final Report of the State Geologist of New Jersey for 1894 (p. 36):

Daily consumption of water for different crops.

	Inch.
Lucern	0.134 to 0.267
Meadow grass	.122 to .287
Oats	.140 to .193
Indian corn	.110 to .157
Clover	.140 to .....
Vineyard	.035 to .031
Wheat	.106 to .110
Rye	.091 to .....
Potatoes	.038 to .055
Oak trees	.038 to .030
Fir trees	.020 to .043

In the Chronique Agricole du Canton de Vaud for June 10, 1901, the general statement is made that forests require only half as much water as cultivated lands of equal area.

leaves and branchlets form a perpetual reservoir for the storage of a large amount of moisture, which is allowed to drain off gradually instead of flowing rapidly into the valleys. Not only does moisture evaporate slowly from the matted leaves lying closely packed in horizontal layers, but the leaves also clothe and protect the underlying soil, which is crumbly and porous and is thus capable of holding a large supply of water. Part of this water is gradually given off to the lower layers of the soil: another part is taken up by the trees to serve in the processes of growth, some of it being ultimately given back to the air by transpiration through the leaves; the remaining part of the original supply is evaporated from the soil and mold. Water distribution, as well as evaporation, has therefore been affected by the reduction of forest areas in southeastern Wisconsin.

EFFECTS OF CHANGES IN THE CHARACTER OF THE FOREST.

The changes that have taken place in the character and composition of the forests that remain standing at the present day have likewise had an effect upon the water flow. Nearly all of the present woodlands have been culled over and are often entirely of second growth, so that their crown cover is probably more open now than it was under primitive forest conditions; while the mold, which has been exposed to wind, rain, and sun, is scant and thin as compared with the former rich, deep soil cover. In the more open spaces of the forest grass and weeds have replaced the protective mantle of shrubbery and saplings, and the soil beneath has lost its porous, crumbly consistency, and has become more compact.

A large proportion of the smaller woodlots are kept in this open condition as a result of pasturing. It is difficult for the rain to penetrate the dense, intricate root system of this new surface growth and to enter the compacted soil. Much of the rain is caught in the grass and herbage and afterwards evaporates, while the vegetation absorbs with avidity what moisture it finds in the upper layers of the soil. The forest suffers under these adverse conditions; the trees begin to dry at the top and prematurely die. (Pl. V, figs. 1 and 2.)

In a rugged, mountainous region it may well be that a grass surface cover is preferable to no cover at all, because it helps to avert washes and floods, but it is nevertheless an established fact that the soil beneath such a cover below the uppermost layers is usually a very dry one.[a] As a great deal of the cultivated area of the region under discussion is pasture land, the effects ascribed to wood pastures can

[a] E. Ramann, in Forstliche Bodenkunde und Standortslehre, an authority on this subject, says, p. 356: "The matted root system of these grasses dries the soil to a considerable depth and interferes with the entrance of the rain water. It has been found that even after prolonged rains the underlying soil often remains absolutely dry."

likewise be ascribed in large part to the cultivated areas. Moreover, the following table shows that these field pastures are even less favorable to water conservation, so far as concerns evaporation, than are areas having no surface growth at all.

Comparison of evaporation, in grams, from a grass cover and from naked soil on areas of 1,000 square centimeters, April 15 to October 31, 1875.[b]

	Grass cover.	Naked.
Sandy soil	47,355	18,312
Loam	51,721	33,899
Peaty soil	55,630	30,290

[b] From E. Ramann's Forstliche Bodenkunde und Standortslehre, p. 264.

It is evident, therefore, that an open forest growth, which not only gives access to sun and wind but also permits the invasion of grass and weeds (the latter being notoriously more severe even than grass in their drainage of water from the soil by evaporation), must affect very unfavorably the moisture-holding capacity of the soil.

The present report has now considered the various causes that may have affected the flow of the Rock River. These have been found to be a slightly diminished rainfall, increased drainage of agricultural land, and changes in the extent and character of the forest. It has been shown that, while it can not safely be asserted that forest destruction has produced any falling off in the annual precipitation over the region, the amount of water which finds its way into the streams—that is, the rainfall minus the evaporation—is somewhat less than it would be had the original forest conditions remained undisturbed. It has also been shown that clearing and use of the forest have combined to produce a great diminution in the power of the soil to hold water, with the inevitable consequence of a more rapid run-off and much wider fluctuations in the volume of the river.

If the changes in stream flow were the result of a climatic change due to the general clearing of the land for farming, there would be nothing further to be said. Since the restoration of primeval conditions is an impossibility, the question of the effects which have followed settlement and utilization of the land is one rather of scientific interest than of practical importance. A proposition to reverse the course of progress and turn an inhabited and productive district into a wilderness in order to increase the rainfall would hardly appeal to sane men. But when the main cause of the evils now complained of is not the lack of rainfall, but the present inability to control the rate at which the water is fed into the streams, the case is very different. A careful examination of local conditions shows that there are within reach feasible remedies, which should at least mitigate the irregularity

of water supply from which the community now suffers, and which can be secured without loss of productive power to the owners of agricultural land, but, on the contrary, with decided advantage to them.

REMEDIES FOR PRESENT CONDITIONS.

For the loss in volume of the Rock River due to diminished rainfall the present report has no remedy to suggest. The whole subject of climatic change is too little understood to permit of any positive assertions in this particular case, either as to its causes or its permanence. The important point practically, however, is not so much the amount of total rainfall as the rate at which it flows off. The remedial agencies needed are such as will help to keep the flow steady.

Drainage is a matter which must be left to each owner to carry out in whatever way will enable him to make the most out of his land, irrespective of the fact that the more fields and swamps are drained the faster will be the run-off and the greater the fluctuations in stream flow. The swamps of the region serve the purpose of very wasteful natural storage reservoirs, which sacrifice a great deal of land to store a small amount of water. Agricultural progress can not be prevented, and should be welcomed; and until the water becomes valuable enough to the interests dependent upon it to make it worth while for them to pay the necessary price in order to store it artificially, the disadvantage of uneven flow due to drainage must be accepted as an incidental drawback of improvements good in themselves.

In the case of the forested area, however, the situation is somewhat different. It is true that here again the controlling principle must be the advantage of the individual owner. It is not proposed to turn good farm land into woods, with the certain result of a net loss on the crop. But there is much land naturally better adapted for woodland than for agriculture. In many cases this now supports a sparse and inferior growth of timber, or none at all. A little care on the part of the owner would result in his having eventually a much more productive and valuable woodlot, and would at the same time help to equalize the stream flow, and so would benefit the whole region.

In most of the woodlots of southern Wisconsin and northern Illinois the forest is in bad shape. The leaf mold has been washed or burned away, or dried out by too much sunlight; the soil has become impoverished; the trees have had their vigor impaired by unfavorable conditions, or have begun to succumb to the attacks of insects and disease; undergrowth and reproduction have been destroyed; the ground has been trampled hard by grazing animals; and the removal from time to time of the best timber, leaving its place to be filled up by inferior growth, has tended to a steady deterioration in the quality and make-up of the forest. These effects are the result of long-continued use of the

FIG. 1.—COURSE OF CATFISH CREEK, SHOWING CHARACTERISTIC LANDSCAPE OF THE ROCK RIVER WATERSHED IN WISCONSIN.

FIG. 2.—LOWER END OF SIX MILE CREEK, ONE OF THE NUMEROUS SMALL TRIBUTARIES WHICH FORM THE UPPER SOURCES OF THE ROCK RIVER.

FIG. 1.—HARDWOOD FOREST OF OAK, HICKORY, BASSWOOD, AND ELM ON A LOW SANDY RIDGE.

FIG. 2.—TAMARACK SWAMP AT LEFT.

forest with too little care of it. In consequence the private owner loses by the smaller yield of timber, and the community loses by the impairment of the water-holding capacity of the soil. If woodland owners can be persuaded that it is a wise policy to restore normal forest conditions on their individual tracts for the sake of the resulting profit to themselves, a marked improvement in sustained stream-flow for the region should follow.

While expert advice is desirable, it is by no means necessary for the woodlot owner to consult a forester before he undertakes to improve his holding. Common sense and thoughtfulness in place of neglect will bring him a certain return. As soon as he has once awakened to the fact that wood is just as much a crop as hay, and that intelligent care will certainly bring a better yield and will increase the value of his property, the farmer will be in a fair way to become his own forester.[a]

PRODUCTIVE POSSIBILITIES OF THE WOODLOT.

The woodlot if properly cared for is money put at interest. The day when a farm is valuable in proportion to the amount of cleared land is long past. A good woodlot is like good buildings, good drainage, and good roads—an improvement with a market value when it becomes desirable to sell. It is often said that trees grow too slowly to be worth the farmer's care in this country, where everyone looks for quick returns. The answer is the daily conduct of the very people who use the argument. The thrifty farmer insures his life, when the woodlot would add insurance at a lower cost and a faster rate; he puts his savings in the bank against old age, though he gets a lower rate of interest than the growth of his trees would yield; he labors to improve his farm in other ways, when a few days' work in the woodlot every year will bring more money for the same effort than anything else he can do; he spends money and time to make his farm look well and takes pride in its appearance, when a little care would make his woodlot the prettiest part of his place. Fuel and fencing all the time, a few logs for timber now and then, an occasional wagon tongue, axle, or bolster, a few spokes or some handle stock when the need comes—the saving of money when these can be got for nothing amounts to a good round

[a] Bulletin No. 42 of the Bureau of Forestry, "The Woodlot," by Henry S. Graves and Richard T. Fisher, although designed primarily as a practical guide for woodlot owners in the North Atlantic States, is a brief exposition of general principles which are widely applicable. It can be obtained from the U. S. Department of Agriculture, Washington, D. C.

Other recent publications which discuss practical forestry for farmers are:

The Practice of Forestry by Private Owners, by Henry S. Graves.. Yearbook of the U. S. Department of Agriculture for 1899.

Practical Forestry in the Southern Appalachians, by Overton W. Price. Yearbook of U. S. Department of Agriculture for 1900.

sum in the course of years. The woodlot, carefully tended, can make its owner independent of coal prices and the lumber yard, besides providing a resource against hard times, when the sale of a little extra lumber makes it possible to draw on past savings. Neglected, it will produce little timber of value, and is all but worthless for anything else.

For the farmer who decides that all his land ought to be made useful instead of only the better part of it, and that paying taxes on idle land is a waste of good money, the suggestions which follow may prove helpful.

COMMON DEFICIENCIES OF WOODLOTS.

QUANTITY AND QUALITY OF STOCK.

It is of first importance that the ground should be well stocked. Usually in this region there are not enough trees to make full use of the land they occupy. To anyone accustomed to the woods this is conspicuous. The openings are large, half the ground is bare of trees and occupied by grass and weeds, undergrowth is absent, and the whole tract looks like a picnic ground. To be well stocked there should be trees enough, old and young, to shade out the grass completely. In the case of pine, an acre should have about three hundred 60-year old or seven hundred 40-year old trees.

To be valuable the woodlot must not only be well stocked, but it must also be stocked with trees of good quality and good kinds. On most tracts the waste in this respect is quite as great as from the deficiency in numbers. The good trees have been cut out: those which remain are the runts, the cripples, and the worthless. Frequently the whole woodlot is occupied by scattering, crooked, undersized trees, many of which are defective with decay, with here and there a few better trees of Elm, Basswood, Blue Beech, or some still less valuable kind. These trees are doing the farmer no good. They are not paying rent; they are not producing half enough wood, and what little they produce is of the poorest kind, crooked and defective even for fuel, hard to get sawed and split, stuff that will not pile into decent cord wood or sell for a respectable price. A poor tree is better out of the woods than in, for it fills up room where a better one might be growing. It takes no more ground or time to raise a White Oak than a spreading Blue Beech, and the former will have $2 worth of railroad ties in it while the beech will make little more than firewood, and none too much even of that. A tree with a crown like an apple or shade tree lays on most of the wood in the limbs instead of the log, and besides takes up too much ground. It is a poor farmer who does not look after the quality of his seed corn, in order after all his labor in plowing and planting and cultivating to gather a full crop. Why should he not apply the same principle to his woodlot?

Bare spaces in the woodlot not only produce no wood; they usually do harm by allowing too much sun and wind to reach the ground and dry out the land. The same evil follows when the woodlot is too open along the edge, so that one can see through it or drive right into the woods at any point. Such an open, park-like condition allows the wind to pass freely through the lot, blowing away the leaf-cover and drying up the ground. Seedlings can not start, the formation of mulch is prevented, and every chance fire is fanned and spread. Such conditions are unfavorable to healthy growth even of old trees, but the effect is most serious on reproduction. It is a common sight to see in one of these open woodlots an abundance of acorns and maple seed on the ground, and yet not a single young plant coming up to take the place of the trees which are about ready to cut. In large forests the border does not matter so much, but a 10 or 20-acre lot is so easily affected by wind and sun that protection is essential if the trees are to grow well and young plants are to fill in the gaps. In summer the border should make a perfect bank or wall of green, impenetrable to the eye.

EFFECTS OF GRAZING.

Such a condition is unattainable if the woodlot is used as a pasture. It would be better if pasture and woods could be separated permanently and completely. Where this is not practicable, a movable barb wire fence ought to keep the stock in the parts where the young growth coming up to take the place of the old trees has got high enough to be out of their reach. Woodland provides sparse pasture. When pastured, it becomes also very inferior woodland. It is a shortsighted policy to let livestock eat up the future forest by browsing the tops off little seedlings on the large number of acres necessary to furnish them this subsistence, if they can be provided for elsewhere on the farm.

Clumps of trees, however, are often a good thing in a pasture, particularly on a stony slope or knob. In such places a few good Hickories, Walnuts, or Sugar Maples may be made to yield nuts or sap as well as growing wood, and at the same time to furnish a grateful shade for the cattle in the heat of the summer. When such clumps are started they should be protected by fencing off until the limbs are out of reach. (Pl. VI.)

EFFECTS OF FIRE.

The woods must be strictly protected against fire. Ignorance and carelessness combine in this country to bring about a preventable annual loss to timber-land owners from this cause, the aggregate of which is very great. It is a public duty to lessen this wasteful destruction by the inculcation of proper principles and the creation of a right

sentiment about fires. The chief trouble is that few people realize the harm of surface fires. As long as full-grown trees are not killed outright, the tendency is to regard the burning over of woodland with indulgence, if not with approval. Often such fires are purposely set to improve the pasture. The farmer is not apt to let his hired man smoke or his boys light matches in the hayloft if he knows it. But in the woods boys and picnickers build fires and smokers drop cigar ends or pipe coals or throw away burning matches without reproof, because in them the ruinous effect of burning off the leaf cover, consuming the plant-food stored in the humus, and killing the young seedlings, without which a forest is like a running stream shut off at its fountain head, is not spectacularly apparent.

The thing about the woods which it is most necessary to keep and most easy to lose is the forest soil. Its porous, sponge-like texture and richness in organic matter are the result of the working into it, season after season, of the moldering substance of leaves and fallen wood. The preparation in this manner of the conditions favorable to healthy forest growth is a long, slow process. Serious deterioration follows drying, packing, or burning this soil. The loss is aggravated on slopes and hillsides by the washing which is inevitable after the soil has been caked or cut by the hoofs of animals, or has been set free from the tenacious network of little root-fibers which permeate it in a healthy forest. That the woodlot fertilizes itself when it is permitted to is no reason why the farmer should expect that part of his land to do well for him without care for the proper condition of the soil, any more than his plowed field.

HOW TO IMPROVE THE WOODLOT.

CARE OF YOUNG GROWTH.

Young growth should receive far more attention than most men now give it. The sapling of to-day is the tree of to-morrow, and must not be wantonly injured or destroyed. Many men, in getting ready to fell a tree, will cut right and left, clearing everything about them in entire recklessness of its future value, and very likely chopping down just what ought to have been left to take the place about to be made vacant. Good, vigorous young timber trees that have got ten or fifteen years' growth ought not to be classed with hazel or alder underbrush and treated as "bushes" or "rubbish." It should be a part of farm training to be taught by father to son, by employer to hired help, to recognize and protect young plants of such valuable trees as oak, ash, and hickory, from the seedling stage up. In felling and trimming, in getting out logs, in the passage of wagons and sleds through the woods, care for young growth should always be exercised.

FIG. 1.—PASTURE WOODS IN WHICH THE TREES ARE BECOMING STAG-HEADED ON ACCOUNT OF DRY AND IMPROPER CONDITIONS OF THE SOIL.

FIG. 2.—HARDWOOD FOREST FROM WHICH CATTLE HAVE BEEN EXCLUDED, SHOWING A PROTECTIVE UNDERGROWTH OF SHRUBS AND YOUNG TREES.

A GROWTH OF HARDWOOD ON THE TOP OF A LOW HILL, SHOWING BEST POSITION FOR FOREST GROWTH IN THIS REGION.

PLANTING.

Where the ground is bare or insufficiently stocked, or where the trees are old, and no young trees are springing up, it is worth while to plant. It does not pay to have even a rod of waste land. A handful of acorns or maple seed or a few dozen plants of pine or spruce and a few hours' work will start a new crop of valuable wood where previous abuse has caused nature's provision to fail. On bad ground such as rocky, steep, poor hillsides, where it is difficult to make these live, plant locust, hazel brush, anything that will grow and hold the ground from washing away rather than leave it bare and getting worse and worse. Afterwards it will be possible to work in something better.[a]

THINNING.

Thinning will sometimes give young growth a chance to start naturally where too heavy shade from a close stand of older trees has prevented reproduction. This condition, however, is rare in the woodlots of the Rock River region. In the same way it is well to notice where a spread-crowned old Blue Beech or other comparatively undesirable tree is keeping down thrifty young saplings of White Oak, maple, etc., and cut it at the first opportunity. It is just as easy in getting out firewood to exercise a little judgment and so improve the tract, as to cut blindly without reference to the future. The best trees and the best kinds of trees should be given a chance to grow in preference to inferior ones. Crooked, stunted, diseased, or limby trees should be taken whenever they can be used. Straight, thrifty young trees should be cut only when they are crowding each other or are hopelessly overtopped. Mere brushwood should not be allowed to choke off good timber trees. A few strokes of the axe will often work wonders in the way of giving the right trees a chance in dense young growth, and many a fine little sapling whose top is whipped bare by rubbing against the limbs of some less desirable neighbor that has got a little ahead in the race may be saved by a single blow. The habit of always carrying an axe when one walks in the woods and taking an interest in the needs of the trees and observing their behavior, will soon give anyone of ordinary intelligence something of the forester's insight into the life of the woods and the way to make them grow and produce timber.

A much fuller discussion of the principles of thinning than is here possible will be found in Bulletin No. 42 of the Bureau of Forestry, "The Woodlot," already referred to. In thinning, however, it is best to proceed cautiously; trees endure much more crowding than most

[a] Further information concerning planting will be found in Bulletin No. 29, Bureau of Forestry, "The Forest Nursery," by George B. Sudworth.

men in this region suppose. To do well there must be vigorous competition among them for space and light. This permits nature to select the most vigorous trees, and greatly assists man in selecting the most valuable. Oaks and Hickories stand least shade; Ash, Elm, Basswood, and White Pine endure more, and Maple and Spruce a great deal of shade.

WHAT KINDS OF TREES TO GROW.

Oak, Hickory, Maple, Elm, and Ash are natives to this region, and can be grown almost everywhere. White Oak should be given preference over Red Oak, and Maple over Elm. In general Elm and Ash should be used sparingly. Maple is an excellent tree to fill in with where the woods need thickening up. In addition to these commonly present kinds a few others may be introduced. Chief among these are Pine and Spruce. White Pine, and White, Black, and Red Spruce are good trees, and are sure to do well almost everywhere. Cherry and Walnut are also good trees, Cherry making a valuable log at an early age. Where posts are much in demand, Catalpa has proved an excellent tree. Black Locust also does well, and is especially frugal, stocking rough, rocky slopes where few other trees will grow.

SPROUT WOODS.

For posts and ties the woods may be run as coppice, or sprout woods. In this case the renewal after cutting is by sprouts from the stumps. To get good results the trees should be cut late in winter, and care should be taken to have the stump slant-cut like a roof, so that water may not collect and hasten decay. As the thriftiness and rapidity of growth of the sprouts will vary according to the vigor of the former tree whose life they continue, the old, rotting stumps of overmature trees should not be suffered to reproduce coppice; young trees from seeds or plants should take their place.

CUTTING.

Cutting should be done in winter and when snow is on the ground. At that time the bark is fast on the trees and least injury is done in felling and in dragging out the logs, the seedlings are covered and protected, and there are no insects active to take advantage of the cutting and multiply to the detriment both of the cut timber and the standing trees. Most of the work should be done with the saw, on account of the greater care which can thus be used. After cutting, timber should not be left stacked in the woods, where it dries out poorly and often begins to decay when summer comes, but should be removed to dry, open ground, where there is a free circulation of air

Finally, the woodlot must not be overcut. It must always be remembered that the amount of wood which is made each year is the interest

or profit on the capital of the woodlot. When more than the increase is taken the capital is impaired; there is not so much wood on hand as there was at the beginning of the year. Increased capital will mean increase in the amount of interest, and vice versa; that is, the more fully stocked the tract, the more wood will be made each year. Large trees which have not reached their maturity generally make in the aggregate much more wood than smaller ones, though they may not grow so fast at a given point; and if they are good saw logs they are making a higher class of timber. It is therefore the part of the thrifty farmer to accumulate rather than to cut wood, until he has brought his woodlot to its best condition. In doing this he will secure a supply of wood for his everyday needs from that which ought to be removed for the improvement of the tract. Then, when his woodlot bank has in it all that it will hold and pay interest on, when the ground is all occupied, not with weeds of trees, but with straight, fine, healthy stock of the kinds most in demand, he may with a clear conscience begin to take his well-earned profit with the full annual product of his capital. He will then easily be able to cut from one-half of a cord to a cord of wood an acre, where now it is doubtful if he could cut half as much without further impoverishing his depleted principal, his sole resource for future supply.

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