REFORESTATION AND WATER RESOURCES.*

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IN RECENT YEARS a great deal of interest has been aroused in connection with the establishing of protection forests. By these are meant areas of woodland or bush which form the watersheds of streams and rivers used for recreational purposes and especially those on which water supplies for domestic use are dependent. In the advocacy of such areas it may be that the pendulum of enthusiasm for conservation has swung too far in one direction, but this is usually the case where reformers of any kind set out to warn the public of an approaching calamity. And it is not an exaggeration to state that if deforestation is permitted to continue on such areas, as it has done in the past, that it will have a calamitous effect on certain of the rural communities in southern Ontario at least.

This enthusiasm for the preservation of forests and the results which will accrue from them, particularly as regards water supply and stream flow, has occasioned a great deal of controversy between civil engineers, hydraulic engineers and others whose work brings them in contact with the control and use of water, and the technical forester or forest engineer, as he is officially known in Canada.

It is not the intention of the present writer to enter into this controversy but simply to mention in passing that he is cognizant of the arguments on both sides and has familiarized himself with the many articles which have been published on this subject. However, all agree that the forest does play an important part in connection with water resources and in this article an attempt will be made to show how this part can be strengthened by the wise use of existing forests on watershed areas and especially by the reforesting of new ones.

At the outset too, it would be well to state briefly what the aims of forestry are and what the work of the Forest Engineer includes. Forestry is the science or art of establishing, maintaining and harvesting woodland crops for profit. In this is included the work of establishing new forests by reforestation, maintaining of forest areas by protection from fire, fungus, insects and other animals and the cutting of the trees when they have reached maturity. Its primary aim is to produce wood, but when one considers the type of soil and the topography of the country which are most suited to the growing of trees, it will be seen at once that it also includes the important subject of protection of water-

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sheds, shelter for fur-bearing animals and the increasingly important role which the forest plays in connection with recreational interests and all that this means financially to a community.

While it is desirable in this paper to stress the need and value of reforestation, all such work when completed may be grouped with existing woodland on the area, and be considered in the one concept,—forest. For after all a forest is just as much a forest whether it be a few years old or a few hundred. The difference is in the size of the trees and the influence it has on its surroundings, but the biological entity is the same.

Furthermore, the science of forestry is related to definite classes of soil. The Forest Engineer has no quarrel with the pioneer who cuts down trees on fertile soil for the purpose of establishing a farm. On the other hand, he does object strenuously to the clear-cutting of forests on land such as poor sand and gravelly ridges which never can become profitable farmland. The same is true of rocky hillsides, with a thin mantle of soil or even steep hillsides of good soil, which form the headwaters of streams. It is these areas of absolute forest soil and submarginal lands which should be reserved for forestry and used to grow trees in perpetuity.

THE FOREST AND THE FOREST FLOOR

A forest has been described as “a plant society governed by definite natural laws the knowledge of which is basic to its intelligent management as an economic resource.” If we examine an area of forest in vertical section what do we find? First of all we have the crowns of the trees with their dense foliage, either broad-leaved in the case of deciduous trees, and needle-leaved in the case of coniferous trees. Here in the spring are the flowers and later on the fruit. Here too is a ramification of branches of all sizes supporting the foliage. Here through the leaves the work of transpiration and the manufacturing of food for the tree is carried on. Coming farther down we pass through the larger branches most of which bear fissured or scaly bark in varying degree depending on the age of the tree. Reaching the ground we observe the roots which are composed of growth similar in structure and development to the branches of the crown. These are the anchors which hold the tree in place, and through the root hairs, at their extremities are the essential feeding parts of the tree. But the function of the roots does not end with giving support and nourishment to the tree, but in the act of extending themselves for food they open up the soil and make thousands of small channels into the ground which greatly increases its porosity. An extreme example of the power of trees to force their roots into the soil can be observed in the rocky areas where quite frequently the roots wedge themselves into the rocks and force them to give way as the tree puts on girth.

The forest floor is perhaps the most important biological factor in the forest. It comprises all the growing plants up to a foot or so in height such as seedling trees, shrubs, trailing vines, both ligneous and herbaceous, a great array of wild flowers, moss and lichens depending on the type of forest. Beneath this is the accumulation of debris which has gathered throughout the life of the forest; made up of leaves, branches, bits of bark, cones and dead herbaceous growth in different stages of decomposition and pressed down by snow of many winters. This is the forest litter, grading into the humus or forest manure and becoming finer in texture until it mingles with the mineral soil.

This forest floor with its mantle of litter and duff of high absorption qualities is most important in regulating water movement on watershed areas. Not so much because it holds some precipitation in suspension to be given off gradually later on; but because it "maintains the absorption capacity of the underlying soil at its maximum."

It is in this layer that the clarifying process of water takes place, which is so essential where reservoir properties are concerned. Zon states that "The soil of the forest was found to contain less albuminoid matter and salts suitable for bacterial growth. Moreover, the humus produced by the growth of trees is inimical to pathogenic bacteria, which, up to the present time, have not been found in the soil of forests (1929).

It was shown that the soil has an important bearing upon the spread of cholera and typhoid fever. In India, it is claimed that villages surrounded by forests are never visited by cholera, and troops are removed to barracks built in the forest to arrest the disease. Huffel confirms this by the statement that the town of Haguenau in Alsace, surrounded by a dense forest nearly 50,000 acres in extent, was always free from epidemics of cholera which in the last century attacked several times the other towns in the same district."

The assistance which the forest floor gives to the absorption of moisture by the soil is largely responsible for the feeding of springs and underground storage. Zon gives over thirty reliable references in Europe and on this continent, to increase and decrease of water in springs in relation to the presence of forest. As many references could easily be gathered in our own province from residents in the rural districts. No one, who has lived in wooded areas of Ontario and has watched the forest being cut down over large areas, will gainsay the fact that the water supply in springs has been changed.

SOILS AND TREE SPECIES

For the purpose of this article soils may be grouped into four classes, namely, rock, sand, loam and clay.

Where the surface of the earth has been folded in the past so that the outcroppings of rock lie at a sharp angle at the surface or where surface rock takes the form of large rounded exposures, or even where limestone lies near the surface in loose layers, the forest plays an incalculable part in regulating water supply and the prevention of erosion. These rocky areas with their many fissures and sink holes feed innumerable underground streams and springs which in turn give back their water to other areas at lower elevations. To remove the mantle of forest humus and its supporting vegetation from such areas is surely provoking nature, for at the time of spring thaw or heavy thunder showers these rocky surfaces will shed water almost as quickly as a tin roof. Such areas represent the poorest class of absolute forest soil and at the southern base of the Laurentian shield, which reaches into the northern part of Old Ontario, they constitute a large proportion of the headwaters of our streams and rivers.

These rocky soils support such species as jack pine, red pine, white pine and hemlock with spruce and balsam on the better sites. Hard maple, yellow birch, basswood, poplar and beech make up the bulk of the hardwoods. An example of this type of forest is found in the districts of Muskoka and Parry Sound and the ability of this mixture of species on these rocky soils to regenerate itself is truly remarkable.

Sandy soil, with which is included gravel, offers less resistance to seepage than any other soil. And even where the gradient is steep if the forest cover is intact, a great deal of water is absorbed. On the other hand, sand is fairly easily eroded by wind as well as water once the protecting cover is disturbed, and for this reason it must be carefully protected with tree growth.

Sand plains and gravelly ridges are the natural home of pine. Where we see in Ontario to-day large acreages of sand land such as those represented by the Normandy Plains of Norfolk, Camp Borden in Simcoe and the ridge of tumultuous sand hills extending through the north part of York, Ontario, Durham and Northumberland; there in years past was the greatest activity in cutting pine lumber.

Such soils besides supporting white and red pine grow white spruce, balsam and some hemlock while cedar and tamarack occupy the moister sites. Of the hardwoods we find most of the well known species represented especially where the soil tends to loamy sand and on bench lands. Such species are, hard and soft maple, beech, birch, basswood, ash, red oak, cherry, elm, ironwood and poplar.

Coming to the loamy soils we find the species run more to the hardwoods which have already been mentioned and the pines peter out. In addition to the common hardwoods we also find such valuable species as walnut, espe-

cially on soils of good depth, butternut, sweet chestnut, the white oak group, and in more southern sections of the province lesser known species such as tulip, sycamore and gum.

Loam also has a high capacity for absorption, in fact it has been shown that a cultivated loamy field either level or of gentle slope will absorb more moisture than a similar area covered with forest. On the other hand, however, loam is very easily eroded and a great deal of damage can be done on watersheds of such soil once the protective covering of vegetation is removed.

Clay soils are the most difficult to handle both from the standpoint of reforestation and control. On such sites the species found are mostly hardwoods while in Northern Ontario a great deal of white and black spruce is growing on clay.

Because of its small particles and gummy nature clay has least power of absorption. Moreover, because of its fine texture it has a tendency when eroded to clog the natural water channels into the soil made by both living and dead tree roots. It erodes very easily and the damage caused by silt from such areas is frequently well nigh irreparable. It is very difficult to control once the surface covering is disturbed and only by persistent planting, and the erection of mechanical barriers over many years can it be finally conquered.

PRECIPITATION AND RUN-OFF

We occasionally hear the statement "plant more trees and conserve the forest and we will have more water in our streams and rivers." Such a statement is only partially true and requires elaborating. Actually forests do not increase the gross amount of water given off by a watershed in relation to the amount of precipitation because this would preclude the use of any of the water by the forest itself. What the forest does, however, is to lessen the violence of a rain storm on a watershed, prevent the snow from melting too rapidly in the spring and, through the agency of the forest floor as already pointed out, hold the moisture for absorption into the soil for underground storage.

By mechanical interference trees are of great assistance in modifying the duration and severity of rainfall. The leaves and branches break the force of the rain. Some of it trickles down the trunks so that much of the water reaches the soil without violence. These same agencies also prolong the duration of rainfall because after a storm, water may continue to drip from the trees for many hours. In this way it has a much better opportunity of being absorbed by the soil.

Forests have a special influence in retarding the melting of snow. This varies of course depending on whether the stand is pure coniferous, pure hardwood or mixed, and the aspect of the site. A forest composed of pure spruce would be the slowest to melt and a stand with a northern aspect of any type would be the last in which the snow would disappear. The amount

Red Pine Plantation, Ontario.

of snow-fall is an additional consideration, as well as the prevailing climate, but there are cases not too far north where snow has remained in the bush for over thirty days after it had disappeared in the open.

Trees and other vegetation use a certain amount of water. Some of this is evaporated from the leaves and trunks, some is used in building up tissue but a great deal of the precipitation is absorbed by the soil mantle. What is left constitutes the run-off.

It should be noted here, however, that although forests use a certain amount of water, the period of greatest use is not at the period of greatest precipitation. In this part of the province the growing period, when trees use most moisture, extends for about five months including the summer. The greatest amount of annual precipitation reaches us in the spring, fall and winter when the trees are dormant or semi-dormant. During this time, however, they are still exerting their beneficial influences with respect to water regulation.

Before leaving the subject of run-off, something should be said regarding the relation between forests and floods. Forest Engineers have never claimed that the forest or reforestation will prevent floods. These are caused by excessive precipitation and extremes of temperature. And the irregularities of rivers can be traced directly to their irregularities. But the forest has a decided mitigating influence on floods. From what has already been said regarding the interference to rain by the trees themselves and the water holding capacity of the forest floor, it can be easily seen that here is a potent barrier to small flood conditions. But when the forest reaches the point of saturation and absorption into the ground is retarded, its work is completed and run-off in large amounts will commence.

The ability of any forest to mitigate floods depends also on local conditions such as geological formation, topography, the size of the watershed and the depth and kind of soil covering it, the character of the streams, their shape, the presence of waterfalls and natural storage basins.

EROSION

Of all benefits which a forest exercises on a watershed area, other perhaps than the supply of wood, none is more important than the prevention of erosion. This, of course, is intimately connected with stream flow and excessive run-off; in fact one has a direct bearing on the other and cannot be considered separately. Wherever the topography of the country is at all hilly erosion of the soil is a factor to be dealt with.

Climate plays a small part in this but such factors as steepness of slope and character of the soil, and especially surface cover, are most important. On rocky areas which have only a thin covering of soil at the most, persistent erosion will result in complete desolation of the area. When the soil consists of sand, loam or clay, erosion can reach colossal proportions, not only by damaging the watershed proper, but also by depositing wide fanshaped layers of sterile soil on good land further down stream. A long catalogue of examples could be quoted, giving evidence of how rivers, harbours and reservoirs have been silted up with eroded material of different kinds.

Different methods have been adopted for the prevention of erosion such as sodding, planting of grasses, shrubs and willows. Gullies have been filled with brush or covered with straw and leaves. Expensive engineering works of stone and log dams and wattle work have been carried out, especially in the mountains of France. Such works are only temporary however, and should be followed by reforestation. In fact on very steep slopes where all ground cover has been removed, something of this sort must be done first before vegetation can be started.

This problem of erosion is of particular interest to engineers in charge of reservoirs because the sediment and the coarser detritus carried by rivers not only increase the stream volume but fill up the storage areas to such an extent that they may become useless. One large reservoir on the Pacific Coast has lost fifteen per cent of its storage capacity by silt in seventeen years. Another on the east coast which lies below large cultivated areas, in ten years was filled up leaving only a channel through the centre for the water to flow.

Critics of reforestation claim that other types of vegetation such as shrubs and grasses of different kinds are just as beneficial for the prevention of erosion as trees. And even where the forest has been cut down on a watershed that the remaining vegetation will sufficiently regulate run-off and prevent erosion as before the forest was removed. This is true to a certain extent although it does not credit the forest with giving additional shade which in turn offsets evaporation, to say nothing of its future economic value in wood products. Of all vegetation, trees are the most efficient for preventing hillsides from eroding and filling up beds of streams with silt. Even on soils of high absorption capacity where the storage of water may be secondary, forest cover is essential as a protection against erosion. Moreover, where it is necessary to protect such areas with vegetation it is cheaper to produce and plant trees than shrubs.

Just here it would be well to state some of the causes which are responsible for severe erosion. The most important of these are forest fires. A forest fire not only injures the large trees if it does not kill them outright, but destroys the forest floor with its capacity for holding water. In fact, in rocky areas, the very soil itself may be burned off which will require hundreds of years for replacement on the part of nature. Faulty methods of lumbering,

which very frequently are followed by fire, is another contributing factor. On protection forests which occupy hilly country no clear-cutting should be permitted. On some of the steeper slopes it is questionable whether any trees either standing or down should be removed at all. No cutting should be done which in any way would interfere with the mantle of forest litter, thereby opening channels for erosion. Unwise agricultural settlement should also be mentioned. This applies chiefly to hilly areas of land of low agricultural worth such as sand and gravel. The cultivation of such hillsides adjacent to streams increases the body of silt and even pasturing has a tendency to disturb the thick turf which holds these areas from being eroded by wind as well as water.

MUNICIPAL FORESTS

As already stated at the beginning of this paper forests which are established by reforestation, or are natural woodland, and which occupy country from which water is obtained for domestic purposes, are usually spoken of as protection forests. And while their maintenance is very essential to a controlled amount of water and the prevention of erosion, nevertheless there is no reason why they should not be considered in the dual capacity of reservoir protection and a municipal forest. In a complete scheme for the control of such streams the areas to be acquired may extend for many miles into the country, and where dams and reservoirs must be established to control flood conditions more land will have to be bought than can actually be used for water storage. Such areas would be the crest of hills, small gullies which contribute run-off and particularly odd pieces of good agricultural land which would be in excess of properties actually needed but would have to be included when purchasing the major part of a man's holdings. These are the areas which could be reforested and incorporated into a municipal forest.

This idea of municipal forests is not a new one. They have existed for hundreds of years in Europe with a great deal of success and profit and during recent years extensive areas of non-agricultural land and watershed areas have been planted for this purpose in the United States. H. F. Prescott of the State of New York Conservation Department in his publication "Municipal or Community Forests" states as follows:

"The average net profit from European town-owned forests is given by J. H. Foster, state forester of New Hampshire, at \$5 an acre and many communal forests in Switzerland yield an annual net return of \$8 an acre. In Zürich, Switzerland, there is a city forest that has been under forest management for over 1,000 years and yields a net revenue yearly of from \$20,000 to \$30,000 which is at the rate of \$4.70 to \$7 per acre per year. Another

Land Which Should Be Reforested.

illustration of the value of a municipal forest, noted by the same authority, is furnished by the village of Orson, Sweden. The people of this town are tax free and have free street car service, telephone, library, schools, etc. In Germany, one town uses a portion of its forest to meet extraordinary expenses for public improvements. In place of issuing bonds for a new school house, public building or other municipal improvement, the town cuts sufficient timber from the reserve section of its forest to meet the cost. In many towns and cities in Switzerland and other European countries, the revenue from the municipal forests pays all the local taxes.

In the United States, municipal forests are still too young to supply any data as to the financial returns that may be expected from them, but it is possible to give an illustration of what one small planted forest actually returned to its owner when cut at the age of 48 years. At East Bridgewater, Mass., in the early seventies, a young man planted a tract of slightly less than 12 acres with small pine trees that he dug up from the neighbouring fields and pastures. In 1921 the trees were sold to make shoe boxes for the neighbouring city of Brockton, the owner of the plantation receiving \$10 a cord

for the lumber on the stump. The forest was cut clean, yielding 589 cords of box lumber worth \$5,890 on the stump, or a trifle less than \$500 an acre. New York State conditions for growing white pine are sufficiently in accord with conditions in Massachusetts to make this illustration of forest returns applicable to this State after making due allowance for accessibility to a market. Several cities in New York State already have planted forests of more than 1,000 acres and a number of others have planted 500 acres or more and are enlarging these forests from year to year. The primary purpose of most of the municipal forests now in existence in this State is watershed protection rather than revenue, but many of the plantations are rapidly approaching the age when they should be thinned for the improvement of the stand. The marketing of the material removed will help pay the cost of maintaining the forest."

In 1935 New York state planted nearly 53 million trees, several states planted over 10 millions. Michigan tops the list with nearly 113 millions while the total for the whole country in this one year was 501,789,763 trees. Most of this work was done by the Civilian Conservation Corps which included upwards of 250,000 unemployed youth of the country.

In Canada the province of Ontario has the largest programme of tree planting and municipal forests, and during 1935 planted and distributed over 10 million trees. Ten counties have commenced one thousand acre municipal forests and several townships and towns have smaller areas. Several municipalities have planted trees in connection with their reservoir properties; notably St. Thomas, Guelph, Hanover, Beeton, Woodstock, Orangeville, Midland and a few others with smaller area. The city of Fort William has a splendid example of a natural protection forest surrounding Loch Lomond from which the city obtains its water supply.

From the foregoing it will be seen that there is an intimate relationship between reforestation and water resources, but this relationship is supplementary. Reforestation will not increase the gross water supply on a small area nor is it intended to take the place of other engineering projects, but it is a supplement of such importance that no complete plan for water supply obtained from watersheds or the control of floods should be undertaken without it.