Fire on the Watersheds of the Nation

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Through the ages wildfire has periodically swept over large regions of the United States, denuding watersheds of their protective covering of vegetation and setting the stage for floods and erosion.

Wildfires had a significant part in causing the erosion in the headwaters that provided the extensive sediments which today are the fertile soils of the Mississippi Valley. Wildfire was largely responsible for maintaining prairie cover on thousands of acres along the eastern edge of the Great Plains, on land otherwise capable of sustaining a hardwood forest.

Some of the most valuable commercial forest stands in the western United States are believed to be the result of fire. Had it not been for the recurrence of fire in the forests of northern Idaho, for example, the famous white pine would long ago have been replaced by the less valuable but the more shade-tolerant western redcedar, western hemlock, and white fir. The fabulous Douglas-fir of western Washington and Oregon owes its abundance in part to fire, which has given it an advantage over the cedar and hemlock that otherwise would predominate on much of the land that is now occupied by Douglas-fir.

In the 19th century millions of acres of the United States were burned, purposely or carelessly, and other millions burned from natural causes without attracting much attention.

Fire was commonly used by the pioneers to clear forest and brushland for crops or forage.

Gradually the need for conservation of the forests and rangelands and the tremendous toll being taken each year by fire began to gain recognition. Fire was first condemned as a destroyer, but soon some of the relationships between fire and soil erosion and flooding were recognized and watershed protection was seen as another potent reason for fire prevention.

As more and more is being learned through research and experience about the relationships between vegetation, soil welfare, and streamflow, the preservation and improvement of watershed values are becoming the principal objective in the protection and management of many of the forest and range lands.

For many years Government agencies, in their campaign for fire prevention, had a tendency to condemn all fire as harmful and destructive. That approach did not ring true to some men in the West who had used fire to remove brush from grazing lands, sometimes with considerable success. The tradition of burning still persists in some parts of the country.

Finally it became clear to some conservationists that the need was great for more thorough knowledge concerning the effects of fire on vegetation and watershed values. Research was undertaken to determine if and how fire could be used as a tool for improved land management.

In 1932 the Intermountain Forest and Range Experiment Station began a series of experiments in the use of fire to control big sagebrush on deteriorated rangelands in southern Idaho. The resulting publication, Farmers' Bulletin 1948, *Sagebrush Burning—Good and Bad*, by Joseph F. Pechanec and George Stewart, gave recognition to the concept that under certain conditions the advantages to be gained by controlled burning could exceed the ill effects.

Subsequently in northern Idaho the Forest Service has undertaken research into the possibilities of using controlled fire in the fight against white pine blister rust. Controlled burning after logging is gaining acceptance in certain situations as a silvicultural practice to clean up undesirable species, to remove diseased or insect-infested trees, promote natural reproduction, or facilitate seeding or planting of desired species. It is becoming a common practice in many western areas to burn wind-thrown timber and other flammable accumulations of fuel under chosen conditions, rather than to risk that wildfire will start in them.

THE RELATIONSHIP between watershed functions and fire is complicated and not completely understood, but some of the fundamentals have been established. The desired watershed function of the land, stated in simple terms, is to receive precipitation and dispose of it in an orderly way. A protecting cover of healthy vegetation and a generous layer of litter and humus on and in the surface soil are essential.

Fire kills or injures most types of plants and consumes part or all of the living plant cover, litter, and humus, thus leaving the surface of the soil bare. When that happens, severe runoff and erosion from intense rainfall might follow. As the raindrops beat upon the unprotected soil surface, the fine particles of soil and ash are stirred about and washed into the tiny spaces between the larger particles, soon making the soil surface practically impervious to water.

This is a common cause of the devastating flash floods that often follow forest fires in the mountains.

The surface runoff from burned areas also causes serious damage to the watershed itself. The water that runs off the surface obviously is not available in the soil to aid the recovery of the fire-weakened vegetation on the land. Besides robbing the plants of water, the surface runoff carries with it some plant nutrients in the ashes and surface soil, thus leaving the soil less fertile than before. The next generation of plants is handicapped in its ability to reclaim the area to its condition before the fire. In much the same way, wind erosion sometimes causes serious damage to burned-over watersheds by carrying away the nutrient-containing ashes, the little remaining humus, and topsoil from critical areas.

The time one watershed needs for complete recovery from a severe fire would be hard to determine. It may be measured in decades for grassland and brushland and in centuries for forest. Considerable progress has been made, however, as soon as enough cover of low vegetation has developed to protect the soil from the beating of the raindrops. That commonly requires one to several years on grass and brush lands, but some severely burned forest sites may be nearly barren for many years. As the protective covering develops, the surface soil gradually loosens up again through the action of insects, plant roots, wetting and drying, and freezing and thawing so that it gradually regains much of its former porosity. In the places where severe erosion has occurred, rebuilding the soil to its former depth and humus content is a long, slow process that is not even begun until the rate of erosion has declined below the rate of the soil-building processes.

Some conservationists tend to feel that recovery has been accomplished when the infiltration rate has improved to the extent that it exceeds the expected rate of rainfall. That is a desirable point in recovery, but it should not give an undue sense of security. Do not the frequent reports of record-breaking rainfall here and there indicate that even our longest weather records give us only a poor indication as to what kind of weather we should expect? It is generally the above-average storm that does the damage, and when the record-breaking rains occur even the maximum possible infiltration rates and water-holding capacities of our watersheds are none too great.

The seriousness of the damages caused by fire depends, not on whether the fire is planned or wild, but on several other important factors: The size and intensity of burn, soil characteristics, steepness of slope, amount and character of precipitation to which the burned area is subject following the fire, type of vegetation present before the fire, length of time the soil will be bare before revegetation occurs, type and amount of vegetation that comes back after the burn, proportion of the watershed unit affected by the fire, characteristics of associated unburned portions of the watershed unit, and condition and adequacy of the stream channel to carry increased flows in an orderly manner.

CONTROLLED OR PRESCRIBED burning, properly planned and executed, seldom results in striking damage, because advantage is taken of favorable combinations of those factors. Planned burning should be done only to accomplish specific objectives and with adequate controls to keep the fire within desired bounds and under conditions of wind, humidity, and fuel moisture that will hold burning intensity to the minimum necessary to accomplish the objective. Repeated burning of the same area should be avoided. Burning should not be done on impervious, shallow, unstable, or highly erodible soils, or on steep slopes—especially in areas subject to heavy rains or rapid snowmelt. When existing vegetation is likely to be killed or seriously weakened by the fire, measures should be taken to assure prompt revegetation of the burned area. Burns should be limited to relatively small proportions of a watershed unit so that the stream channels will be able to carry any increased flows with a minimum of damage.

When burning is done under those conditions, the advantages gained in control of weeds or brush, improved silvicultural relations, reduced fire danger, or other ways may outweigh the limited damage done to watershed values. Fire should still be recognized, however, as a drastic and dangerous treatment and must be allowed only after careful weighing of all the values at stake gives reasonable assurance that burning is justified. Thinking people must not accept controlled burning on lands with high watershed values as a satisfactory practice, but must constantly be on the alert for safer ways to gain the desired goal.

Meanwhile, whenever controlled burning is contemplated, those responsible should always be sure that they are complying with local, State, and Federal regulations and should take full advantage of the best guidance available for the type of burning to be done. Assistance or guidance in the form of publications can frequently be obtained from local fire wardens, county agents, local offices of the State forestry or conservation departments, State extension service, Forest Service, Soil Conservation Service, Bureau of Land Management, and others.

WILDFIRES, or any poorly executed planned burning, are always dangerous and often very damaging. They always occur without regard to the factors that control their damage potential; often they occur under conditions that favor their spread. When that happens, the other factors, too, are likely to be at their worst. Millions of dollars are spent for the prevention and suppression of wildfires on the Nation's watersheds, and still many thousands of acres are ravaged by fire each year.

Some of the fires, by destroying the water-controlling ability of the watersheds, have been responsible for floods that have caused tragic loss of life and tremendous property damage. An example is the flood which struck La Crescenta, Calif., on December 31, 1933. It took 30 lives and did damage estimated at 5 million dollars. The flood arose primarily from recently burned parts of the watershed above. Unburned watersheds nearby handled the storm with little or no flooding.

Near Yucaipa, Calif., fire started on July 4, 1950, and burned some 630 acres of chaparral-covered foothills. On July 6, while mop-up crews were still on the fire, an intense thunder shower dumped about three-fourths inch of rain over the burn and surrounding area. The resulting flood blocked roads below with sediment and debris so that bulldozers were needed to aid removal of the fire equipment. Several thousand dollars of damage was done by the floodwaters from the burned area, yet little or no water flowed from adjacent unburned drainages.

FIRE ON CROPLANDS is becoming less common each year as farmers learn the advantages of incorporating organic matter into the soil instead of burning it. Fall burning is especially undesirable, because it exposes the soil to wind and water erosion and to deep penetration by the concrete type of frost in winter.

Fire on grasslands does much more damage than is generally recognized. Fire, as it consumes the vegetation and litter, releases some of the stored plant nutrients in readily available form. When they are leached into the soil by gentle rain or snowmelt they sometimes promote lush and rapid regrowth of the unkilled plants or growth of new seedlings. The removal of the old vegetation by fire also tends to make any new green growth show up to better advantage than when it is partially hidden by old vegetation and litter. The especially lush, green appearance of grasslands after a fire, actually attributable to those two causes, is often wrongly interpreted to show that fire is in some way beneficial to the grass. The reduction in growth in succeeding years after the extra nutrients have been used up or washed away may go unnoticed.

Actually, fire kills or weakens many of the desirable forage plants. When heavy rains wash away the ashes and additional topsoil, thus robbing the plants of nutrients and water, damage is worse. Runoff from burned grasslands often heightens flood damages. Erosion once started on grasslands following a fire frequently continues for many years, even after the vegetation has recovered.

Many brushland fires are set each year in mistaken attempts to eradicate the brush in the hope that grass will increase. Although rather safe and effective methods have been developed for eradicating big sagebrush by fire in southern Idaho, that is not the case for many other undesirable kinds of brush and chaparral. Burning to control brush should not be attempted, except by thoroughly approved methods. To do otherwise is a useless waste of natural resources and time.

In California there are about 20 million acres of brushland or chaparral, most of which is of very little value except to protect the steep, erosive watershed lands. Yet millions of dollars are invested in equipment and facilities for fire prevention, detection, and control, and other millions are expended each year to control fires that do get started. These costs are justified by flood damages prevented.

The chaparral frequently makes considerable recovery in 3 or 4 years, but at least 40 years are required for the vegetation to regain maximum density. If severe erosion has occurred meanwhile, it doubtless takes much longer for the soil depth and water-holding capacity to be restored. Though the intensively developed and heavily populated valleys give watershed protection an especially high value in California, brush fires have much the same effect in other parts of the Nation as they have there and must be controlled wherever they occur.

SEVERE FOREST FIRES on high-value watershed lands represent just about the ultimate in destruction and waste. Such fires are even more serious than brush or chaparral fires. The effects last longer and are more complex.

Forests generally receive more precipitation than brush or grass lands, or they would not be in forest. Much of the forested mountain land in western Washington and Oregon and some in northern Idaho, western Montana, and northern California receive more than 60 inches of precipitation a year. In some places as much as 40 to 60 inches of water is stored in the snow pack on high, steep, mountain areas around the first of April each year.

Heavy rain on fire-damaged watersheds may result in severe flood damages in the valleys below.

The snow generally melts in 2 or 3 months; that means that the watersheds must handle water at the rate of 20 or 30 inches a month on the steep lands. In such situations the importance of the forest stand for water control cannot be overestimated.

At the Coweeta Hydrologic Laboratory in North Carolina cutting all vegetation from a heavily forested watershed and leaving the vegetation on the ground increased total runoff from the watershed by 17.29 inches the first year. The next year, because of water use by sprout growth and low vegetation, the increase was reduced to 13.35 inches. Though the situation is somewhat different in regard to a heavy burn on forest land, the figures give at least a rough idea of the possible increase in total runoff that may be expected following a forest fire.

Soil freezing is an important factor in soil-water relations in the northern half of the United States east of the Rocky Mountains. In that part of the country forest fires which remove the insulating cover of litter and humus promote soil freezing and development of a more impervious type of frost than is found in soils high in humus and protected by plant litter. Bare soils puddled by rain and then frozen may become practically waterproof, while protected soil high in humus, even though frozen hard, generally is not frozen solid and is still permeable to water. Spring rains that run off the surface of bare frozen ground frequently soak into and hasten the thawing of protected soil. Thus increased surface runoff, soil erosion, and flooding from snowmelt or winter and early spring rains are a common result of forest fires in areas where the soil usually freezes in the winter.

Snowfall accounts for most of the precipitation received on many of the heavily forested watershed lands in the Rocky Mountains, Sierra Nevadas, and Coast Range, where it often accumulates to great depths. The ground under those heavy snow packs is seldom frozen in snowmelt periods.

On larger burns, say of 50 to 100 acres or more, it is likely that somewhat more snow gets to the ground or snow pack than under the forest cover, largely because the unburned forest cover intercepts more of the snow before it reaches the ground. The magnitude of difference will depend on wind, temperature, and size and frequency of snowstorms. Cold, dry, snow, falling in large amounts and accompanied by wind, may mostly get to the ground, even through dense forest cover. Then the distribution will be rather even under the trees and drifted in the open burn, but the average amount reaching the ground may not be much different. But light falls of wet snow may be largely intercepted by the unburned trees and evaporated back to the air before the next storm, so that little of it ever gets to the ground. If this type of storm accounts for a large proportion of the snowfall, the amount reaching the ground may be considerably greater in the burn.

Whether it then accumulates to a heavy pack, melts, and soaks into the soil, or evaporates, depends on the weather between storms. On the average, however, the amount of snow reaching the ground in a large burn may not be very much greater than in a large unburned area.

Small burns within a large forested area often collect considerably more snow than the adjacent unburned areas. One explanation for this may be that the winds tend to move across the top of a forest much as they do across the surface of a field, so that a depression such as is formed by a small burn tends to cause eddies in the wind currents, thus causing them to drop their load of snow into the openings.

Snow may generally be expected to melt somewhat earlier and more rapidly on burned than on similar, but unburned, forest land. The difference is more pronounced on south and west slopes in seasons of much sunshine. The snow may then disappear 1 to 3 weeks earlier on the burned areas. On north slopes and in seasons when the melt is strongly influenced by warm airmasses, accompanied by cloudy skies, the difference may be negligible. In either instance, the total runoff, if any, from melting by sunshine or warm airmass will be greater from the burned than from the unburned because of reduced interception and lack of available storage space in the soil.

When lots of sunshine induces appreciably earlier melting on burned-over than on unburned forest land the difference may be harmful or beneficial, as far as its effect upon streamflow is concerned. Melting generally is more rapid in the latter part of the season than early, because of longer days, hotter sun, warmer nights, the accumulation of heat-absorbing particles of dust and trash on the surface, and the aeration of the pack as sticks and stones begin to protrude. Therefore an early start may be beneficial in getting the snow off the burned area with the least disturbance. The early melting may tend to reduce the peak flow of streams by prolonging the melt, or it may have the opposite effect. For example: A fire that denudes the south slopes of a mostly timbered watershed might have a locally beneficial effect on the flow of the first stream. Further downstream, however, the early higher-than-normal flow from the burned area may coincide unfavorably with the normal peak flow from lower elevation or grass-covered drainages, to cause flooding there. Similarly, burning of the forest from a partially grass-covered watershed may result in local flooding if it causes melting on the formerly timbered portion to coincide with that on the grassland.

The warm airmass type of snowmelt, such as was largely responsible for the 1948 flood in the Columbia Basin, is most likely to occur late in the melt season. When, as in 1948, it follows a late spring in which the normal early-season melt did not occur, the results are likely to be disastrous. Warm airmass melting gains much of its danger from the fact that it is likely to continue day and night in open or shade on all aspects through a wide range of elevation. In contrast, sunshine melt stops at night, and allows for natural scheduling of runoff, because snow on south slopes at low elevations and on open land generally melts before that on north slopes, higher elevations, and shaded areas.

During warm airmass melting, the principal direct effect of fire is probably the contribution of an excessive amount of water from the burned area and the greater probability of surface runoff and erosion, especially if rains accompany the snowmelt. The excess water is greatest in the first year or two following the fire and gradually decreases as the use by vegetation increases.

Recovery of the watershed is a long slow process after a severe forest fire. Return of a protecting vegetative cover generally is fairly prompt in the hardwood forests of the East because trees and shrubs may sprout from the stumps or roots after a fire. Most coniferous trees, however, are killed by a hot fire. In fairly open stands, species of shrubs, weeds, and grasses may survive and provide a cover of sorts within a few years. But when some of the dense stands of tall conifers are killed, it often takes many years before even a low cover of grasses or weeds becomes established, because the seeds must come from beyond the burned area. If left to nature, recovery in such cases normally goes through several slow stages of succession; first nothing but bare ground, snags, and erosion; then gradually mosses, weeds, grasses, and perhaps a few shrubs; gradually, the shrubs take over, with perhaps a few tree seedlings here and there; after many years the trees finally begin to crowd out the shrubs, but it takes 100 years or more for a tree to grow big and probably a couple of generations of trees before the soil depth lost by erosion has been replaced.

THE DESIRABLE PRACTICE of seeding or planting burned forest land to hasten recovery is gaining in popularity, but the annual burn will have to be greatly reduced and the planting rate multiplied before they will be in balance. Even if all burns could be replanted promptly, it still takes about a century to grow a tree.

Avalanches of snow or earth often occur on steep slopes following forest fires in the heavy snow country. Once avalanches get a slide path established they may occur annually or periodically for decades. When they dump their loads of rock, earth, and debris into a stream channel they may be a practically permanent source of channel instability and contribute greatly to flood damages. Even the natural creeping of fire-killed snags down steep slopes may be a significant factor in causing or maintaining unstable channel conditions for a half century or more following a fire. That is the situation in some of the northern Idaho and western Montana country that has been ravaged by big fires.

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The Management of Public Watersheds

G. R. Salmond and A. R. Croft

Nearly as old as the hills themselves is the thought that conditions on the hills influence streamflow, erosion, and sedimentation.

The ancient Chinese had a proverb: "To rule the mountain is to rule the river." No doubt it was rooted deep in centuries of Chinese experiences. But the Chinese did little about it; vast mountain areas in China are now a total waste and rivers are choked with sediment caused by the destructive force of water on the watersheds.

The Greek philosopher Plato about 400 B. C. spoke out with the clarity of a modern conservationist: "There are mountains in Attica which can now keep nothing but bees, but which were clothed, not so very long ago, with fine trees producing timber suitable for roofing the largest buildings, and roofs hewn from this timber are still in existence. There were also many lofty cultivated trees, while the country produced boundless pasture for cattle.

"The annual supply of rainfall was not lost, as it is at present, through being allowed to flow over a denuded surface to the sea, but was received by the country, in all its abundance—stored in impervious potter's earth—and so was able to discharge the drainage of the heights into the hollows, in the form of springs and rivers with an abundant volume and wide territorial distribution. The shrines that survive to the present day on the sites of extinct water supplies are evidence for the correctness of my present hypothesis."

George P. Marsh, the United States Ambassador to Italy in 1861, recognized the terrible destruction of the soil over past ages. Impressed by its consequences, he wrote a book, *The Earth as Modified by Human Action.* Citing about 400 examples, he concluded