Managing and Protecting Forest Water Resources

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One of the most important functions of forest land is the delivery of fresh water for drinking and sanitation, for agriculture and industry, and for recreation and wildlife. Where water is scarce and the demand is high, water may be the single most valuable product of forest land. Managing and protecting forest water resources is becoming an ever more difficult, more complex, and more important task.

Forests cover about 30 percent of the total land area of the United States, but an estimated 75 percent of the Nation's water supply originates on this land. In the Western States, high-elevation, largely forested watersheds produce some 90 percent of the usable water. With growing populations, especially in the West, the demand for water is increasing.

Besides water supply, forests are used for timber production, mining, grazing, waste disposal, recreation, and numerous other purposes. These activities may adversely affect forest water resources. The water resources of many forest lands are already impaired. U.S. timber demand in the year 2030 is predicted to be double that of 1976. Increased demands for other forest resources are anticipated as well. In addition, the total forest area is expected to decrease as forested land is converted to other uses.

Researchers have an interesting challenge—to provide the new information and technology necessary to protect and manage water in the face of ever-increasing pressure on all the forest's resources.

Public concern for water was responsible, in part, for the establishment of our National Forest System. Some 154 National Forests contain about 190 million acres of federally owned forest land that were reserved from the public domain or purchased for the protection of critical timber and water resources. In addition to its many other uses, this land has served for more than 50 years as a vast open-air laboratory for the study of forests and water. The research branch of the U.S. Department of Agriculture's Forest Service maintains for research purposes about 90 designated experimental forests on National Forest lands.

Water Supply

While much of the United States has abundant water, water supply in some areas is far less than the demand and is a limiting factor in resource development and economic growth. Water-supply projections indicate that by the year 2000, people living in 17 major river basins in 11 Southwest and Midwest States and in some localized areas in the Northeast and East will suffer serious water shortages. Demands for water for nonconsumptive purposes such as fish, wildlife, and recreation also will increase.

Watershed scientists are studying ways to increase the production of water from forest lands. It was once thought that forests conserved water, making more water available for streamflow. Researchers have found that this is not true. In general, trees need and use more water than do other types of vegetation. Forested lands yield water simply because forests tend to develop on those lands where water is most available.

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Maintaining high-quality water for fish and wildlife is an important aspect of forest management. North Central Forest Experiment Station technician measures dissolved oxygen and temperature in an experimental wildlife impoundment.

A large share of the water falling onto a forest as precipitation is returned to the atmosphere as water vapor. Trees take up large quantities of moisture from the soil that is then lost to the air by transpiration through the leaves. In addition, water evaporates directly from the soil, and some rain and snow is intercepted by the tree crowns and evaporates before it ever reaches the ground. The water that is left over flows from the forest in streams or as ground water and is available for other uses. The water leaving an area as streamflow is called runoff and is measured in units of depth. Ten inches of runoff, for example, means that if all the water leaving as streamflow were spread evenly over the area from which it came, it would be 10 inches deep.

Runoff from forest land has been measured on dozens of experimental watershed areas in the United States. Where precipitation is barely enough to support tree growth, such as along the boundary between the eastern forests and the prairies, and in many places in the West, annual runoff may be as low as 1 or 2 inches. Average runoff from the eastern forests and from the high-elevation forests in the Rocky Mountains is about 10 to 20 inches a year. In the Appalachian Mountains and in the coastal mountains in the Pacific Northwest, this figure is 20 to 50 inches or more.

Numerous studies on forested watersheds have shown that when the trees are cut down, annual runoff as streamflow increases because losses of water by transpiration and interception are reduced. If most of the yearly precipitation occurs as snow, as

In 1956 Rocky Mountain Forest and Range Experiment Station scientists began a long-term study of the effect of forest-cutting practices on water yields by cutting a steep slope in a pattern of strips and patches. Snow accumulates in the openings, and the water yield from cutover areas is higher than from uncut control areas.

is the case at high elevations in the Rocky Mountains, runoff can be increased further by cutting trees in a pattern of small clearings, where snow then accumulates.

The greatest increases in water yield occur where precipitation is the highest. Increases are generally proportional to the percentage of the tree cover that is removed. Clearcutting in the high precipitation zones of the Southern Appalachian Mountains can increase annual runoff by as much as 16 inches. Water yield increases usually decline rapidly as new trees grow back. Flows may return to normal in as little as 5 years. Where streamflow comes mostly from snowmelt, water yield increases may persist for 20 years.

Where water is scarce and the demand is increasing, it may become practical in the future to harvest timber to increase water yield. The first application of this technique would probably be in the headwaters of the Colorado River. In the more humid East, timber harvest to augment low summertime flows may be considered in some areas.

Many questions, however, remain. Researchers need to learn more about the effects of changing snow deposition patterns on snowmelt and streamflow, the long-term stability of stream channels with increased flows, the identification of those combinations of soil, geology, and tree species that will give the largest increases in water yield, and much more. Also, timber harvesting must be planned and carried out in such a way as not to increase sedimentation or otherwise degrade water quality.

Erosion and Sedimentation

As the United States was being settled, the best lands—those most level and most fertile—were put into agricultural uses. Today, many of the remaining forests occupy land that is too steep to farm. Steep slopes make this land highly susceptible to erosion. When undisturbed, forest cover protects the soil from erosion. Disruption of the forest cover by timber harvest, road construction, mining, heavy grazing, or wildfire can increase erosion rates by a factor of 10, 100, or even more, compared to undisturbed sites. Erosion has a double effect on the forest: it depletes the soil, and the deposition of eroded materials as sediments in lakes and streams degrades the water resource.

Sediment is probably the greatest cause of water-quality degradation on forested land. The highest rates of sediment production from U.S. forest land are in the Northwest and the Southeast. Sediment destroys aquatic habitat and impedes human use of the water. Many kinds of fish need clean gravel beds for spawning, and aquatic insects on which fish feed live among the pebbles and cobbles on the stream bottom. When sediments bury these areas, the effects on aquatic life can be severe. In the Pacific Northwest, for example, the impacts of forestry-related sediment on the salmon fishery is a serious problem. Numerous reservoirs, large and small, store water from forested areas for municipal use, irrigation, power production, flood control, and recreation. Sediment from poorly managed forest land can fill these structures, reducing their usefulness. Sediment suspended in the water increases the cost and difficulty of water treatment for municipal use.

Researchers are studying in detail the erosion process on forest land and are finding new ways to reduce erosion and sedimentation. In timber harvesting, for example, in areas where landslides do not occur, simply cutting trees does not significantly increase erosion. The machinery and logging roads needed to move the trees from the forest, and sometimes preparation of the site to establish the next stand of trees, are the major problems. Road surfaces and cut-and-fill slopes erode rapidly. In addition, poorly designed roads intercept, concentrate, and channel water, increasing its erosive power. New road designs and techniques for revegetating cut-and-fill slopes will help to alleviate this problem, as will advances in machinery and logging methods. Where surface mining is carried out on forested lands, scientists are investigating ways to reshape the land to minimize sediment production, and to revegetate barren lands as quickly as possible. Computer modeling of erosion and sedimentation will point out problem areas where additional care is needed.

In some forests dominated by steep, unstable slopes, timber harvesting can trigger landslides that deliver large amounts of sediment to streams. This is common in the Pacific Northwest and coastal Alaska. Here, tree roots are especially important in helping to hold the soil in place on the slopes. When the trees are cut, the roots decay within a few years and landslides occur. Scientists have investigated this process and developed techniques to identify those areas most susceptible to landslides, where trees should not be cut.

Temporary increases in sediment are almost inevitable when forest cover is disturbed, especially on steep slopes. But if forest activities are carried out carefully and research findings are applied, sediment can be held to a minimum.

Plant Nutrients

Trees and other plants require various chemical nutrients to grow. As fallen leaves and other dead plant materials decay, the nutrients they contain are released to the soil, from which they are taken up again by living plants. Some nutrients, such as nitrogen and phosphorus, are in relatively short supply and are recycled efficiently. Only small amounts escape from the system to enter lakes and streams. When trees are harvested, nutrient uptake by the vegetation is temporarily decreased, and the leaching of nutrients into the water increases. In certain situations, it can significantly affect water quality.

The production of algae and other plants in forest lakes and streams is normally limited by the small amount of phosphorus available. Nitrogen may sometimes be limiting as well. Additional phosphorus and nitrogen reaching the water from timber harvesting or other forest disturbance can trigger increased production of aquatic plants. In infertile, unproductive waters, some increase may be desirable, but larger nutrient inputs can result in thick blooms of algae that make waters unsuitable for municipal or recreational use and cause undesirable changes in aquatic ecosystems. High concentrations of nitrogen in the form of nitrate are deleterious to human health and harmful to aquatic animals as well.

Researchers are finding ways to reduce these nutrient losses from the forest, thus maintaining the fertility of the soil while protecting the water resource. As more forest land is being fertilized with phosphorus and nitrogen to increase timber production, this protection becomes increasingly important.

Wastewater Treatment

Forest land can be used for wastewater treatment. Even after treatment at a conventional sewage treatment plant, municipal wastewater contains high concentrations of phosphorus and nitrogen. Cities and towns are often located near rivers and lakes, into which this treated sewage is dumped. Nuisance growths of algae, premature aging of lakes, fish kills, and general degradation of water quality are typical results.

Research has demonstrated that municipal wastewater can be applied to forest lands with many beneficial results. Nitrogen and phosphorus are retained by the forest, where they increase tree growth. When precipitation is scanty, the forest also benefits from the additional water. And, lake and stream water quality is improved. As demands for both timber and clean water increase in the future, application of wastewater to forest land will become more common.

Pesticides and Other Chemicals

A variety of chemicals are applied to forest lands in the United States, including insecticides, herbicides, fungicides, rodenticides, bird repellants, and fire retardants, to favor the growth of desired tree species and to minimize the undesired effects of some environmental factors. A major concern is the prevention of water pollution from these chemicals.

Scientists have found that such chemicals can enter the water by several means. They may be applied directly to lakes or stream channels during broad-scale operation, if care is not taken to prevent it, or they may drift on the wind from applications to nearby areas. Water flowing over the surface during a storm or snowmelt may wash applied chemicals from the land, either dissolved in the water or attached to sediment particles. Chemicals also may be leached through the soil by water, but this is the least likely pathway since most chemicals such as pesticides are tightly held by soils.

As forest management becomes more intensive to meet the increased demands for timber, the use of chemicals on forests will likely increase. Future research will show where and how these chemicals can be used effectively while still meeting water-quality standards and protecting aquatic and riparian habitat.

Acid Rain

The smelting of sulfur-bearing ores and the burning of fossil fuels release sulfur and nitrogen oxides into the air that return to earth in precipitation as sulfuric and nitric acids. The popular term for this phenomenon is acid rain. Where the deposition of acids is high and the capacity of the landscape to neutralize acids is low, lakes and streams become acidified. Populations of fish and other aquatic organisms become stressed and ultimately die out. Various toxic metals that may be present in the watershed dissolve more readily in acidic water. If this happens, acidified water may become unfit for drinking.

Many areas in the United States are forested today because the land is too poor for agriculture. Soils may be thin and underlain by bedrock or may consist of coarse, infertile sands. These lands may have little ability to neutralize acids in rain and snow. Scientists are assessing the impacts of acid deposition on the water resources of these forests.

In the 1950's, acidic precipitation in the United States was limited to New England and the mid-Atlantic States. Since then, acidic precipitation has spread. Today, the most acidic precipitation still occurs in the Northeast, but most of the eastern half of the country and some isolated areas in the West now receive acidic rain and snow. Lake acidification in the United States was first seen in New York's Adirondack Mountains. Researchers have now found evidence of lake and stream impacts over a much wider area. A study of lakes in the forests of Minnesota, Wisconsin, and Michigan shows that lake acidification across this region is occurring in direct proportion to the acidity of rain and snow. Changes in stream water chemistry related to acid precipitation have been noted in the mountains of North Carolina. Sensitive, high-elevation lakes in the Rocky Mountains are being studied, as well as the forest water resources near population centers on the West Coast.

Researchers are investigating the complex interactions among precipitation, vegetation, soils, geology, and lake and streamwater chemistry. By understanding these processes, they can predict how forest water resources will be affected by future levels of acid deposition, whether deposition increases, decreases, or stays the same. This information will help legislators to set reasonable and responsible acid-deposition standards.

Determining the Effects of Atmospheric Deposition

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What Is Atmospheric Deposition?

The quality of the air can affect trees and forests in many ways. Through the air, trees receive water, nutrients, and gases (such as carbon dioxide) that are essential for their growth. During recent years, forest managers and the public have become concerned that polluted air may be adversely affecting the health of trees and forests in large regions of the United States.

This concern is a part of the important environmental issue known as acid rain. Acid rain (or snow or fog) is literally precipitation that contains abnormally high concentrations of acids (especially sulfuric acid and nitric acid). These acids may end up in streams, lakes, soils, and plants—possibly changing the ecological balance and causing detrimental changes in terrestrial or aquatic ecosystems. In addition, acids (or chemicals that can be converted to acids) may be deposited on the land in dry form, and potentially harmful gases also may be deposited. All these chemicals may influence the health of forests. Considered together, these chemicals are called atmospheric deposition.

Why Is There Concern About Forest Health?

Scientists have long known that atmospheric deposition of certain pollu-