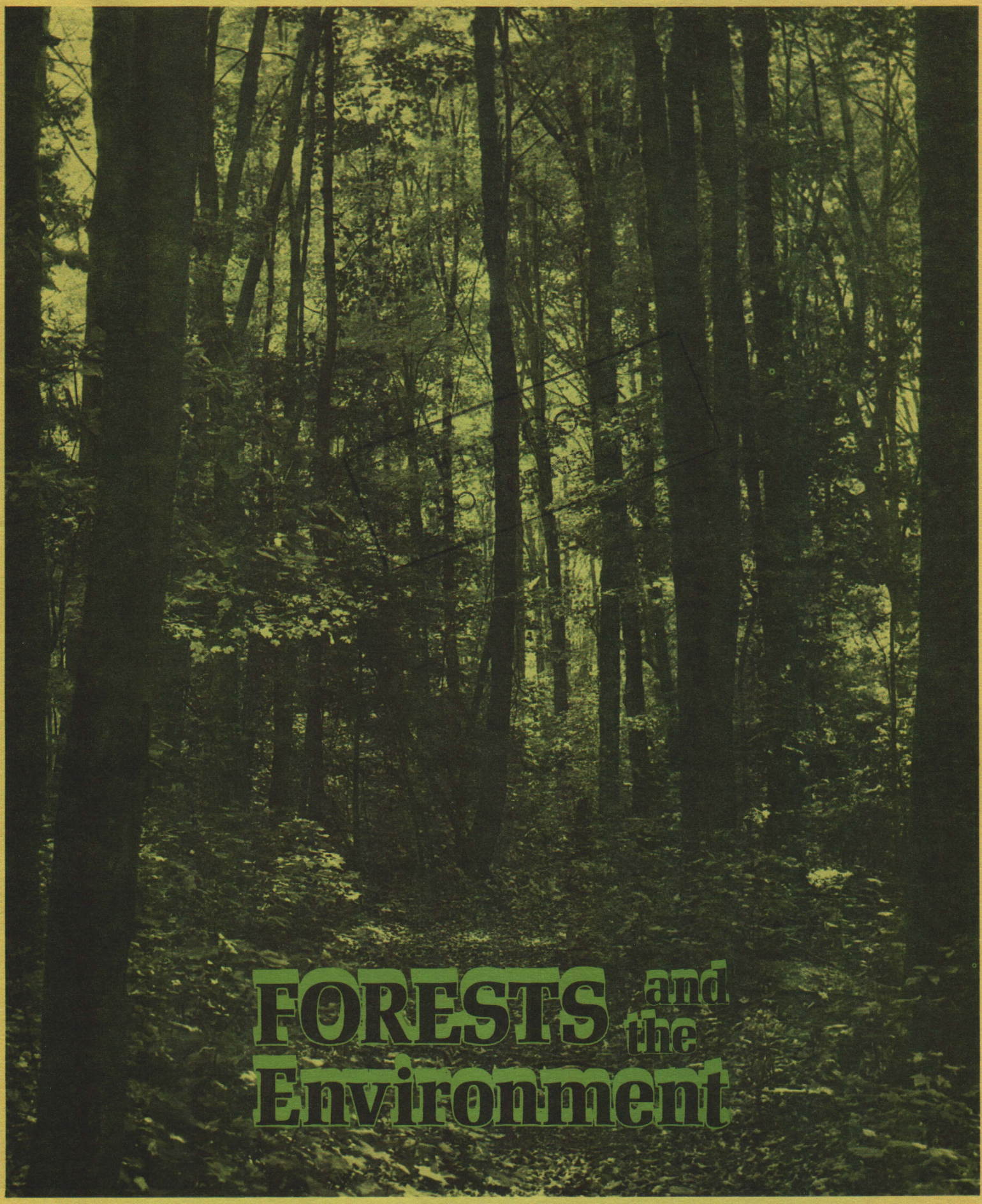


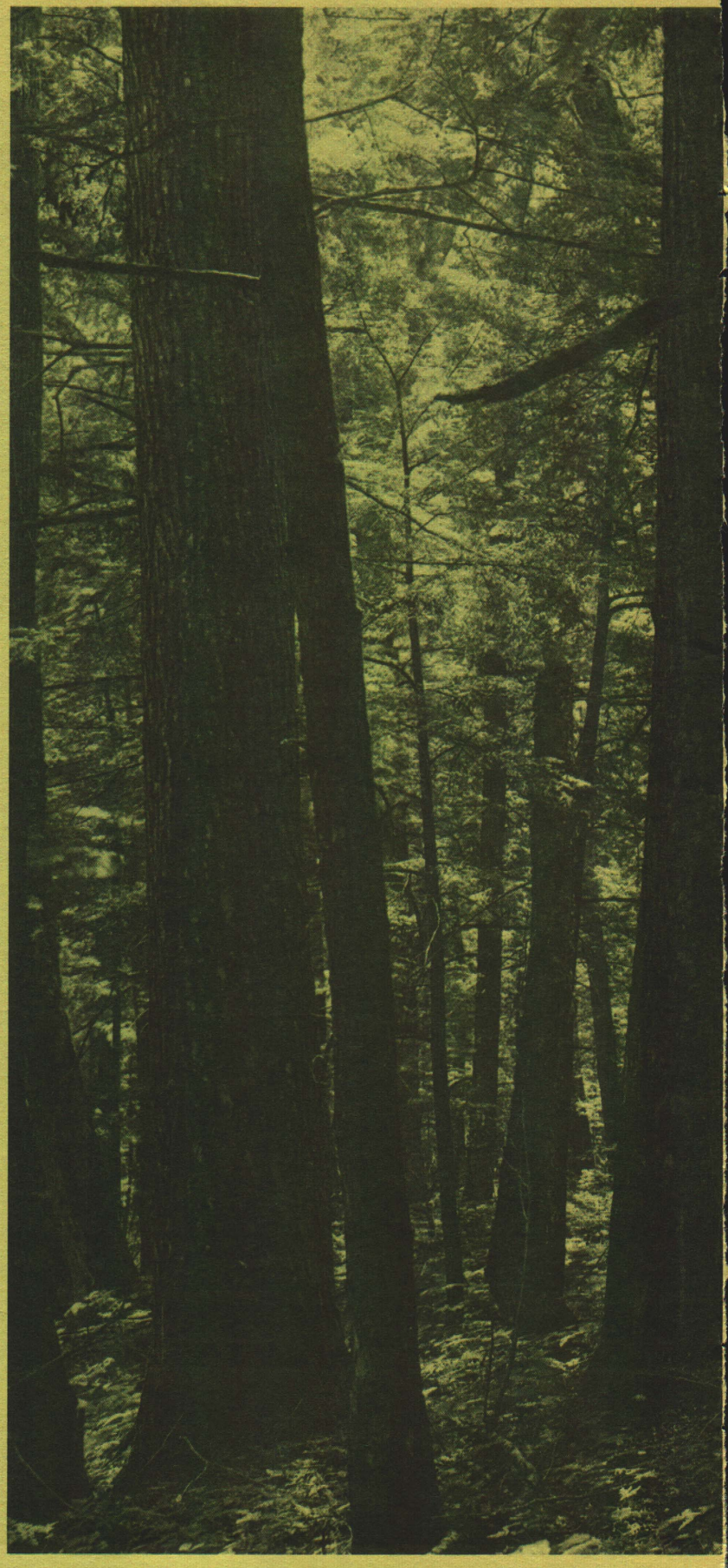
FORESTS and the Environment

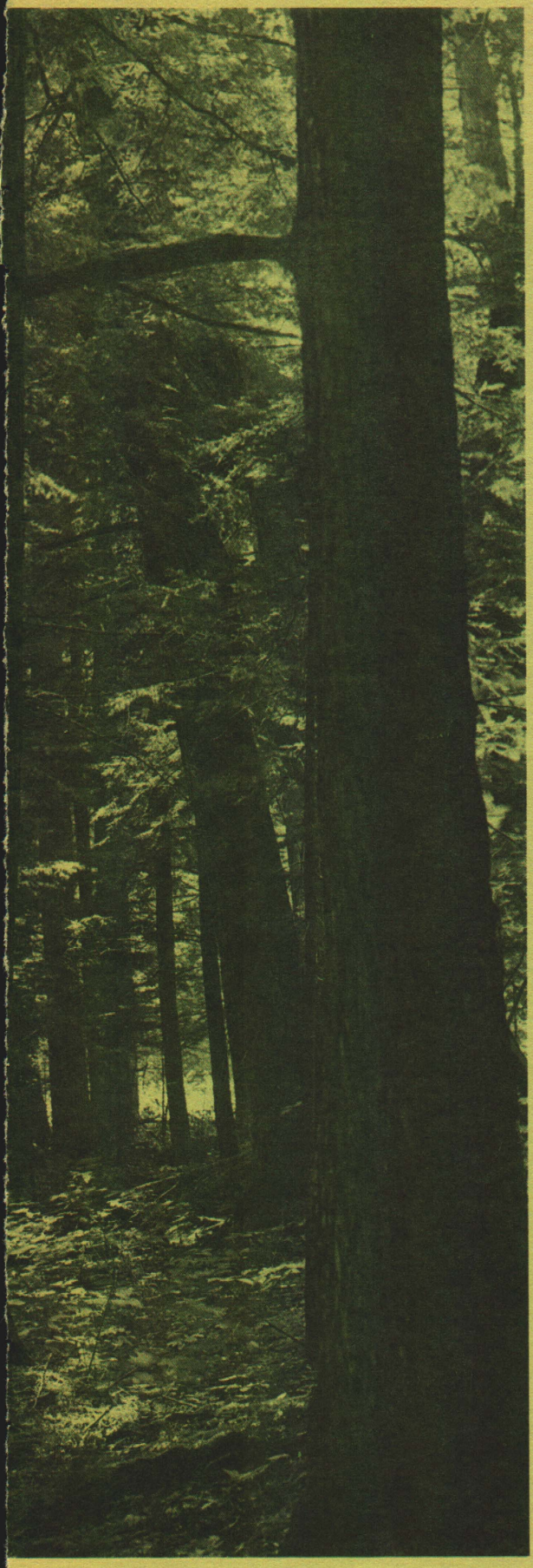
COOPERATIVE EXTENSION SERVICE MICHIGAN STATE UNIVERSITY

Extension Bulletin E-716 Natural Resources Series October 1971

CONTENTS

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. George S. McIntyre, Director, Cooperative Extension Service, Michigan State University, East Lansing, Michigan. 1P-30M-10:71-HP





From the dawn of civilization, forests have been a very important part of man's environment. They have always supplied many of man's basic needs — material, aesthetic and spiritual. Through careful management, forests yield countless products for man's use and enhance environmental quality at the same time. This bulletin focuses attention on the less obvious, but very important, ways in which trees and forests contribute to make our environment more stable.

FORESTS and the Environment

By Roy E. Skog, Melvin R. Koelling and Lester E. Bell[1]

Forests are a very important part of man's environment. Their value for timber, wildlife, recreation, water, erosion control, and aesthetics has long been recognized. But, forests also screen dust from the air, suppress loud noises, dissipate unpleasant odors, produce atmospheric oxygen, reduce atmospheric pollutants, and temper the climate. For people seeking relief from the busy world, forests provide a place of quiet, rest and inspiration.

Forests are a relatively permanent type of land cover. Unless seriously disturbed by man, widespread catastrophe, or major climatic change, forests persist indefinitely on a given area of land. Their contribution to the ecological stability of nature benefits many forms of life, including man.

Forests account for a large portion of man's environment. They cover one-third of the land area of the earth, one-third of continental United States, and slightly over one-half of Michigan. Forest influences are felt by people in rural and urban areas as well as in remote wildernesses. The importance of individual trees, groves of trees and small forests near and within cities is becoming increasingly understood and appreciated.

1. Extension Specialists, Dept. of Forestry, Michigan State University.

FIG. 1. *This northern-hardwood, climax forest is aesthetically pleasing, and provides habitat for many wild animals.*

FOREST ECOSYSTEMS

The concept of an *ecological system*, or *ecosystem*, is helpful in understanding important roles of forests and how they contribute to the quality and stability of environment. "Ecosystem" is a biological term applied to an area or unit of nature which includes both living organisms and non-living substances. Within the ecosystem, interactions occur that produce an exchange of materials between the living and non-living. A lake, river, grain field, conifer swamp, redwood grove, and deciduous forest is each an example of an ecosystem. The boundary of an ecosystem may be well defined (e.g. a pond), or it may be poorly delineated as is often true of forest areas. A forest ecosystem may encompass a few acres or many thousands of acres.

Natural ecosystems consist of these four major components: 1). abiotic (non-living) materials; 2). producers; 3). consumers, and 4). decomposers. Abiotic materials include water, carbon dioxide, oxygen, and the numerous nutrient elements needed by plants to survive and grow. Producers are green plants of all kinds. Consumers are large and small animals, including insects. They depend on plants for food, either directly, or indirectly. Through the harvest of forest products, man is a major consumer in many forest ecosystems. The fourth component in land ecosystems – decomposers – are primarily fungi and bacteria present in the upper soil layer. Decomposers break down plant and animal material so portions of it can be recycled and used again as food by plants.

Nutrient materials essential for plant and animal life may be re-used many times in natural ecosystems.

Some ecosystems are simple in their make-up, while others are highly complex. A wheat field is a relatively simple ecosystem, while a deciduous forest is complex and highly diversified. The more complex an ecosystem, the more resistant it is to change or damage by insects, disease, storms, pollution and other disturbances. In general, *climax* ecosystems are more complex and more stable than *pre-climax* ones. Climax ecosystems are those that have evolved over a considerable period of time through a process known as *succession* – one stage of development gives way to another until a stable or climax stage is reached.

The deciduous forest of sugar maple, beech, basswood, oak and other hardwood species, as commonly found in Michigan, is a good example of a climax ecosystem (Fig. 1). An acre is likely to be stocked with a thousand or more trees, including five to ten different tree species, ranging in size from saplings to large timber trees. On the same acre, thousands of seedlings, shrubs and herbs usually cover the ground, while the soil teems with billions of bacteria, fungi, soil mites, earthworms and other organisms. Varied types of animal life, both large and small, inhabit deciduous forests. Because of its diversity, the deciduous forest can withstand considerable damage to plant and animal life, and yet continue to function effectively as an ecosystem. Often, an entire species may be lost without seriously affecting the gross productivity of the forest. Thus, when plant or animal losses occur, others are usually present to perform similar functions. Contrast this with the effect on production from loss of a single species in a less complex ecosystem, such as a trout pond or corn field.

As a climax ecosystem, the deciduous forest is also highly conservative of plant nutrients. When leaves, twigs, branches and trees die and fall to the ground, they are soon decomposed and returned to the soil. Litter and humus covering the soil hold water run-off and accompanying nutrient losses to a minimum. On the other hand, the mature deciduous forest (a forest in which trees have reached old age and slowed down in growth) is like all mature climax ecosystems – not highly productive. Food and oxygen it produces is used primarily to sustain itself and the mature deciduous forest grows timber at a very slow rate. In fact, there may be no net growth because of serious tree decay and mortality. However, through good management, including harvest of mature trees and forest improvement, its timber productivity can be increased and maintained at a high level (Fig. 1). The deciduous forest can also provide game, recreation, beauty and other values while still functioning as a stable ecosystem.

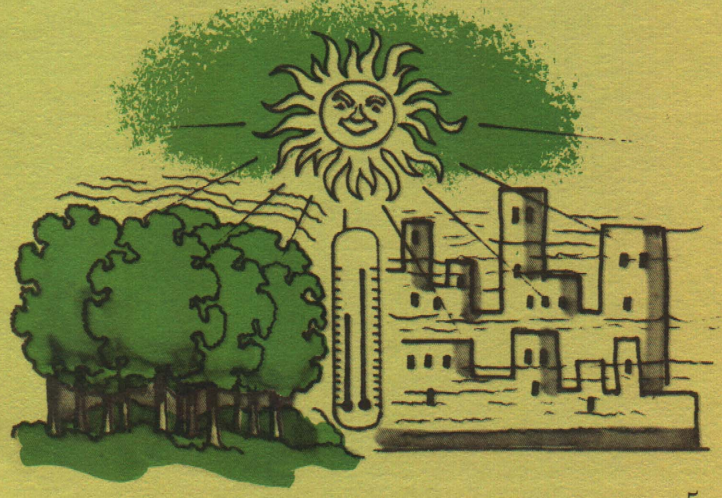
BENEFICIAL EFFECTS OF FORESTS

Forests affect environment in various ways that benefit man either directly, or indirectly. An awareness and understanding of these benefits help us appreciate the value and importance of forests. Understanding these effects can also be helpful to persons responsible for managing forests and caring for trees.

MODERATE AIR TEMPERATURE

The forest canopy (leaves and branches of trees) reduces the amount of sunlight that reaches the ground and acts as a blanket to reduce heat radiation from the ground. Within a forest, this helps moderate temperature extremes, making days cooler and nights warmer than in an adjacent clearing. During warm summer weather, the temperature in a forest might be as much as 8°F. cooler during the day and 6°F. warmer at night than in nearby open areas. Forests sparsely stocked with trees have less effect on air temperature than dense forests. In winter, deciduous forests have little or no effect on air temperatures.

Trees also cool surrounding air as a result of water loss through *transpiration*. In this process, moisture moves from the soil through the trees to the leaves where it is evaporated into the air. During a hot summer day, a large shade tree evaporates up to 100 gallons of water through transpiration. The accompanying cooling effect is significant. It has been estimated that the cooling provided by one large shade tree may be equivalent to that produced by five or more room-size air conditioning units.



Moderating effects of trees and forests on air temperature make forests pleasant for camping, hiking and picnicking during warm weather. In urban areas, single trees and groves can significantly cool parks, streets and homes during hot weather.

REDUCE WIND VELOCITY

The canopy of forests is very effective in slowing down wind movement. In a forest of shade-tolerant trees where the canopy extends nearly to the ground, velocity of the wind is relatively uniform from ground level to near the tops of tree crowns. In stands that are open beneath the canopy, as might be true in an old-growth pine forest, the difference in wind speed within the canopy and near the ground is often appreciable.

The extent to which a forest will decrease wind speed is largely dependent on tree density and wind velocity. A wind of four miles per hour might be reduced only slightly. A wind of 30 miles per hour, however, might be reduced to as little as 5 miles per hour in a dense forest(3).

Windbreaks are frequently planted to protect homes, farmsteads, orchards, fields, industrial sites, playgrounds and other areas from the effects of high winds and drifting snow(6). They generally consist of three or more rows of trees (sometimes shrubs) planted at right angles to the direction of prevailing winds, so as to provide leeward protection (Fig. 3).

Effectiveness of a windbreak depends primarily on its width, density, height and length. A dense planting of several rows of trees and shrubs will reduce winds of 20 to 25 miles per hour by about 75 percent close to the planting(2). Even at a distance of 20 times the height of the windbreak, wind will be reduced about 20 percent on the leeward side.

Spruce and pine trees are commonly planted for windbreaks in Michigan. Deciduous trees are also planted, but lose their effectiveness in winter.

SUPPRESS LOUD SOUNDS

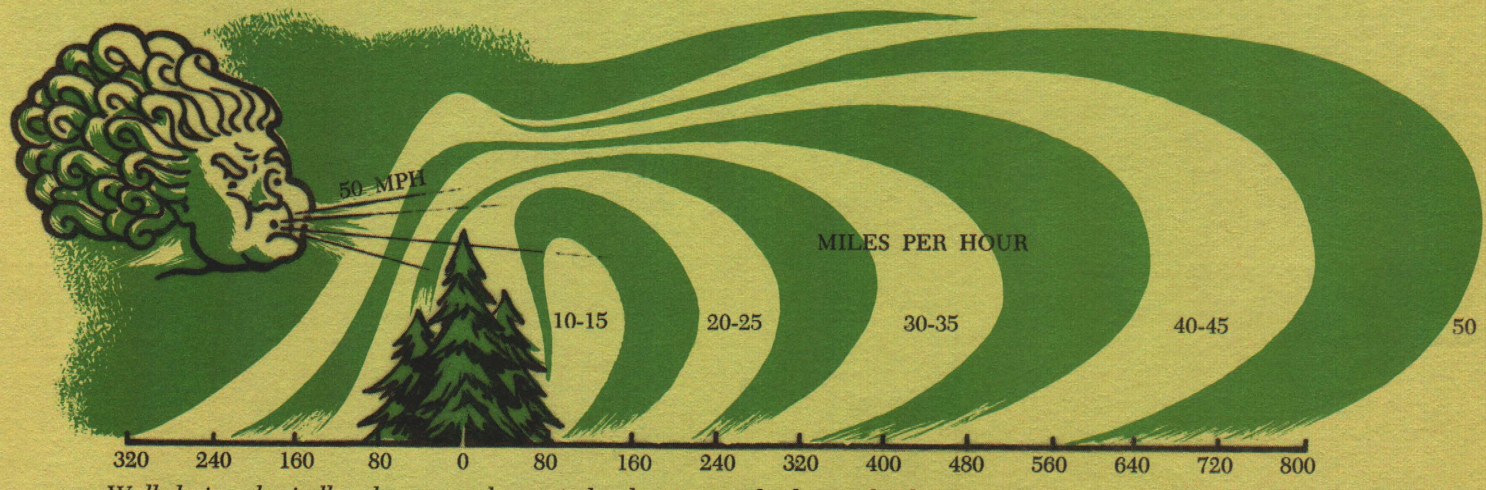
Forests absorb sound and make it less intense (10). Sound passing through each 100 feet of forest may be reduced by six to eight decibels. Thus, a forest barrier 200 feet wide can reduce sound 12 to 16 decibels; one 300 feet wide, 18 to 24 decibels.

Above an intensity of 50 decibels, sound becomes uncomfortable to the average person. Intensity of some common sounds are:

Sound	Decibels*
Jet aircraft	140+
Car horn	110
Express train or Chain saw	100
Dog barking	92
Busy intercity highway	72-78
Normal speech	48

*A decibel, the unit used in acoustics to measure the intensity of sound, is the faintest sound audible to the human ear.

The effectiveness of trees as sound barriers is influenced by their size, density and location, as well as terrain, wind, humidity, air temperature and other factors. A barrier of trees has little effect on sound coming from above the canopy, such as aircraft, but is particularly effective in reducing sounds on level areas, especially if the sound source is lower than the receiver. A forest or tree barrier may suppress sound sufficiently to make a noisy location a relatively pleasant place to live. For example, a tree barrier 300 to 400 feet deep along a busy highway can suppress traffic noise to a tolerable level for residents living this distance from the highway (Fig. 2).



Well designed windbreaks may reduce wind velocities on the leeward side for a distance approximately equal to forty times the height of the trees.

FIG. 2. *Traffic noise from busy highways is absorbed by roadside forests.*

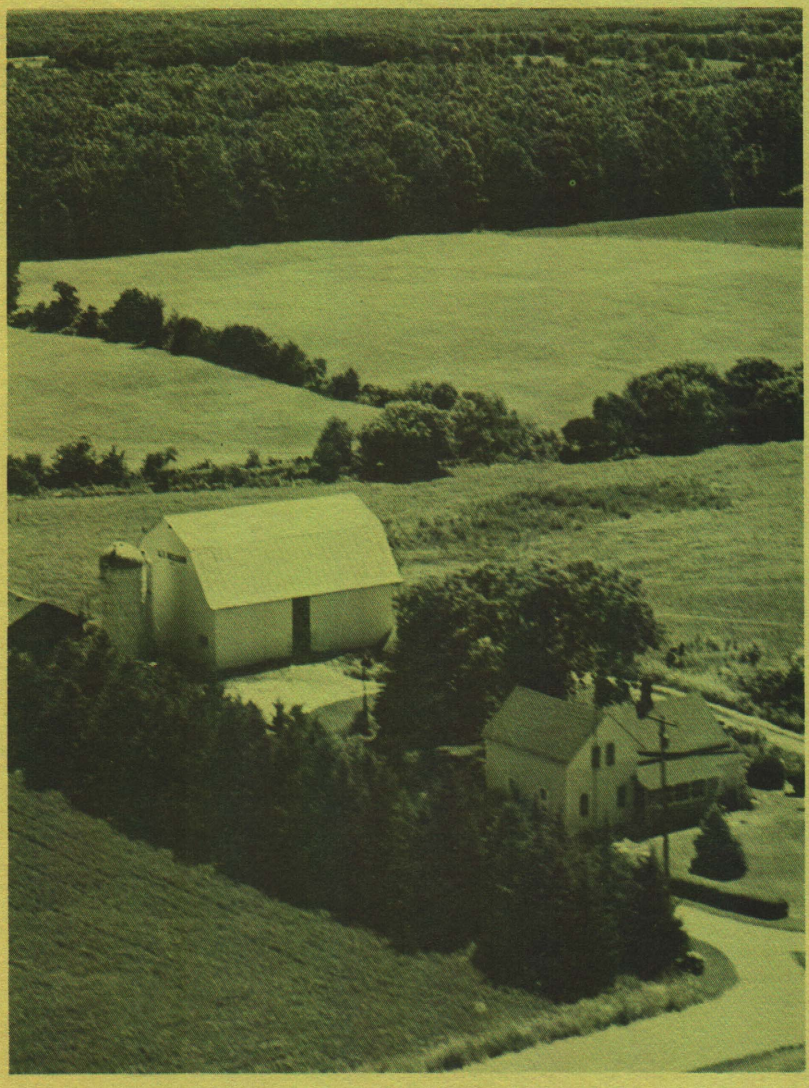
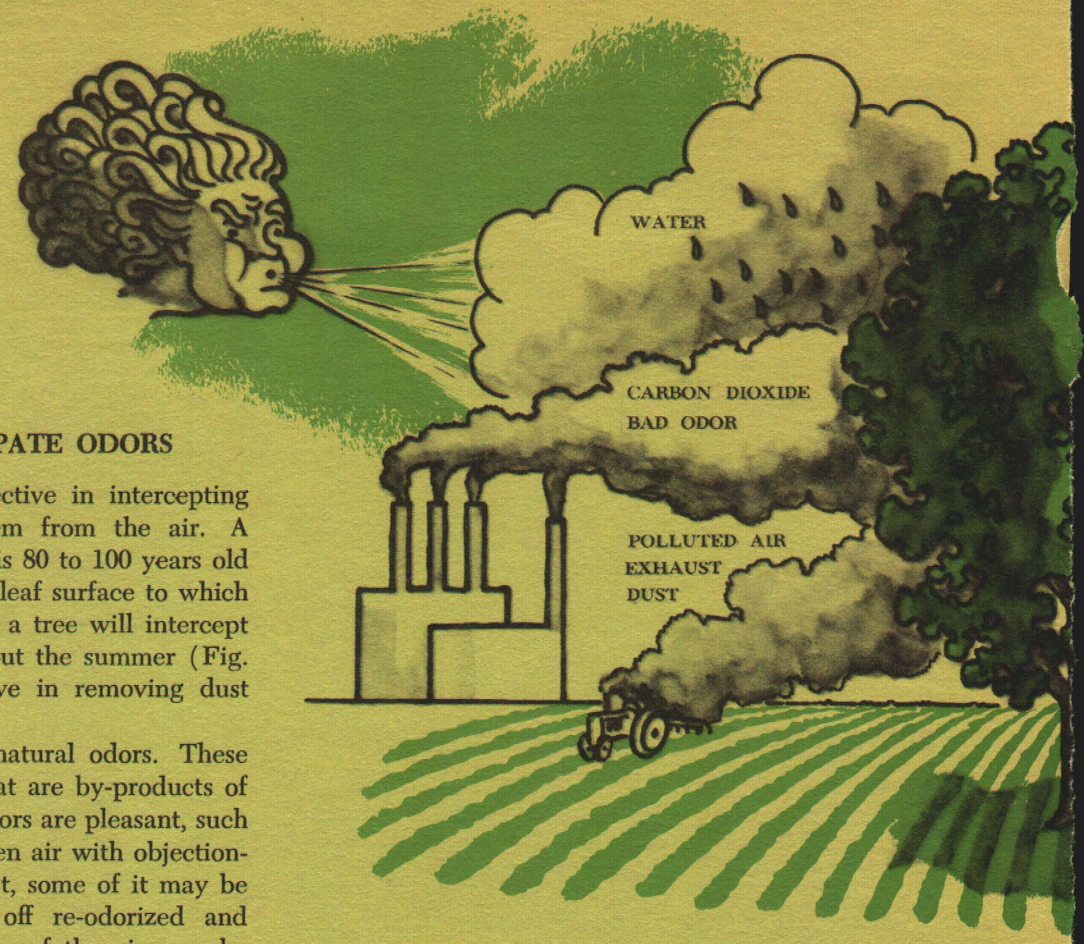


FIG. 3. *This windbreak protects the homestead from high winds and drifting snow. Photo by USDA Soil Conservation Service.*

FIG. 4. *Shade trees have a cooling effect on streets, sidewalks, homes and yards. Trees also filter dust from the air and suppress noise.*

FIG. 5. *Forests are pleasant for camping, hiking and picnicking because of the moderating effects of trees on temperatures.*



COLLECT DUST AND DISSIPATE ODORS

Leaves of trees are very effective in intercepting dust particles and filtering them from the air. A deciduous tree, like beech, that is 80 to 100 years old has about 1,600 square yards of leaf surface to which dust particles can adhere. Such a tree will intercept several pounds of dust throughout the summer (Fig. 4). Evergreen trees are effective in removing dust from the air all year.

All species of trees give off natural odors. These come from volatile chemicals that are by-products of tree metabolism. Many of the odors are pleasant, such as the smell of pine forests. When air with objectionable odor passes through a forest, some of it may be absorbed by trees and given off re-odorized and higher in oxygen. Other portions of the air may be sufficiently diluted to reduce or eliminate the objectionable odor. In rural and urban areas where odors and dust are a problem, properly located belts and groves of trees can help clean the air and make the environment more pleasant.

BALANCE CARBON DIOXIDE AND OXYGEN

All food and fiber produced by plants, and indirectly by animals, is dependent upon photosynthesis. This is the process by which green plants use sunlight as energy to combine carbon dioxide from the air with water to manufacture food for their own use and food and fiber for man. Oxygen is a by-product of this process and significant amounts pass into the atmosphere for use by all living organisms.

Life on earth is geared to a global atmosphere containing 21 percent oxygen and slightly more than 0.03 percent carbon dioxide. Atmospheric oxygen is, of course, necessary for the survival of all animals, including man. Carbon dioxide is essential to plants for carrying on photosynthesis.

Man and his activities consume more and more atmospheric oxygen, and emit increasing amounts of carbon dioxide into the air. The world's human population, which now totals about 3.5 billion has been projected to double by the year 2,000. In the burning of fossil fuels (coal, natural gas, petroleum products, etc.) modern technology uses enormous volumes of oxygen and gives off large amounts of carbon dioxide. As a result of these processes, the amount of carbon dioxide in the air is believed to be increasing. Measurements made from 1900 to 1969 indicate a seven percent increase (1). While the effects of increased carbon dioxide in the air are not fully known, there is some fear that further increases could have a serious warming effect on the earth's climate.[2]

Green plants, including ocean plankton, play a vital role in maintaining the supply and balance of oxygen and carbon dioxide in the air. Because of their vast extent and tremendous areas of leaf surfaces, forests of the world acount for about half of the carbon dioxide-oxygen exchange accomplished by all living plants (18). It has been computed that for every ton of wood grown, forests consume 1.47 tons of carbon dioxide and release 1.07 tons of oxygen.

Tree plantations of all kinds, trees on home grounds, along streets, and in parks, are also important in

2. It is difficult to say what effects changes in the atmosphere might have in the long run on the world's climate. Carbon dioxide in the air tends to absorb infrared rays (heat energy) coming from the earth and radiate them back to earth. This has a warming effect on the climate. Dust particles in the atmosphere reflect sun rays away from the earth, and this has a cooling effect.

maintaining the balance between carbon dioxide and oxygen. Managing forests and trees to keep them healthy and vigorous increases their capacity to perform this important ecological role.

WARN OF AIR POLLUTION

Burning fossil fuels, and various industrial processes, release many air pollutants that are toxic to man and plants. An estimated 95 percent of the plant damage attributed to air pollution in the United States is caused by sulfur dioxide, fluorides, ozone, PAN (peroxyacetyl nitrate) and PAN related compounds (20). Ozone probably causes more injury to plants than any other air pollutant (8). Taken up by plants in sufficient amounts, these pollutants can cause slow growth, leaf discoloration, lesions on leaves, breakdown of chlorophyll (chlorosis), and poor seed production. Damage may be so slight that it is invisible, or severe enough to cause plant death.

There are many sources of air pollution. Sulfur dioxide comes from burning coal, operations of petroleum refineries, smelting of ores, manufacture of sulfur and other sources. Fluorides are produced in the manufacture of aluminum, steel, ceramics and commercial fertilizers. Ozone is naturally present in very small amounts in the upper atmosphere and is also produced electrically in the air by storms. In densely populated and heavily industrialized areas, considerable amounts of ozone and PAN are formed photochemically in the air by the action of sunlight on nitrogen dioxide and certain hydrocarbons coming from motor vehicles and other sources.

Air pollution has caused serious damage to forests in certain parts of the United States. An example of extensive damage is a tract of over 160,000 acres of ponderosa pine forest in Southern California (14). There, a high proportion of trees have been affected, of which three percent have died. Damage is attributed to PAN-type compounds as found in smog. Likewise, there has been fairly widespread damage to white pine in Midwestern and Eastern United States from sulfur dioxide and ozone. This disorder, known as *chlorotic* dwarf, has also been identified on plantation Norway spruce, Scotch pine, and Douglas-fir (5).

Polluted air is a serious health hazard to man and believed to be a contributor to the increased incidence of respiratory diseases. Certain species of forest trees serve as sensitive bio-indicators to warn man of dangers from air pollution. For example, white pine, boxelder, and sycamore species are relatively sensitive to low levels of ozone (8).

In the processes of photosynthesis and respiration, trees take-in and expel large volumes of air. The extent to which these processes reduce air pollution is not known. However, research has shown that tree respiration substantially reduces ozone content. It is quite possible that other air pollutants are reduced in the same way.

FIG. 6. *Care was taken in thinning this red pine forest for poles. It is neat and orderly in appearance.*

ENHANCE AESTHETICS

Forests and trees add beauty and interest to the landscape and make surroundings for homes, outdoor recreation, business and industry more pleasing. In managing forest tracts, it is often possible to apply or modify management practices for esthetic purposes. For example, when timber is harvested, openings can often be created to bring into view scenic hills, streams, or lakes. Harvests of timber can be made in patterns that harmonize with the landscape. The selection method of timber harvest may actually contribute to the development of a forest that is esthetically more pleasing than the uncut forest (17). Thinning and other cultural work carefully done likewise enhance the attractiveness of a forest (Fig. 6).

Many people consider logging destructive to the forest's natural beauty. The forest manager and logger can reduce the visual impact of logging and shorten the period during which the scars of logging are apparent. Careful felling and skidding of trees will minimize damage to uncut trees. To reduce visibility and hasten decay of logging slash near roads, lop and scatter slash (tree tops and limbs). Fell unsightly cull trees and trees badly damaged by logging. Logging machinery should not be abandoned in the forest, and all debris should be removed or buried. Whenever necessary, measures should be taken to control soil erosion.

PROVIDE WILDLIFE HABITAT

Many wild animals not only depend on the forest for food and shelter, but are also an essential part of forest ecosystems. Variation in the composition of forests creates more favorable wildlife habitat than a continuous forest of only one, or a few, tree species. Forests in which there are scattered openings with borders of shrubs and brush (Fig. 7) provide good habitat for a wide range of animals, including deer, ruffed grouse, and rabbit. Timber harvesting encourages reproduction and growth of young trees and shrubs that provide food and cover for wild animals. Planned timber harvests over large areas are a good way to increase and maintain a supply of deer browse. Planting food-producing shrubs, where conditions for their growth are favorable, will also increase supplies and cover.

FIG. 7. *Openings in forests create favorable habitat for many wild animals.*

FOREST INFLUENCES ON SOIL AND WATER

In most forests, litter and humus accumulate on the ground from decaying leaves, branches, tree trunks and other vegetation. In some virgin, spruce-fir forests, humus may reach a depth of three to nine inches; in old-growth hardwoods, a depth of two to five inches (11). As humus decays, nutrients are released and enrich the upper soil layers. The humus layer also has another important effect. By shielding the mineral soil from direct impact of falling rain, it helps maintain the naturally high water infiltration rate of undisturbed soils. The penetration and decay of roots and activity of countless soil organisms help make forest soils crumbly and porous. Because of their structure and composition, many forest soils have a very high water-holding capacity.

EFFECTS ON SOIL EROSION

Forests in which the litter and humus covering the soil remains undisturbed are very effective in controlling erosion and accompanying nutrient losses from the soil (4). This is because there is little or no water runoff from the surface of the soil. Tree cutting does not result in erosion, provided the soil cover is not disturbed. But, it is important to protect forests from livestock grazing and fire. Heavy grazing and intense fire will destroy the humus layer, resulting in soil compaction and serious erosion.

When logging in hilly country is done with care, it seldom causes serious erosion or change in the quality of water reaching streams (7). Careful planning of the road system to minimize road construction and the area of mineral soil exposed helps reduce erosion considerably (9). Erosion can also be reduced by building roads on the contour, proper road drainage and completion of the logging operation as soon as possible. Erosion can be further controlled by promptly seeding road shoulders (Fig. 8), roads which are infrequently used, and log yarding areas. Leave uncut strips of forest along streams to help prevent sedimentation of streams and stream bank erosion.

EFFECTS ON WATER SUPPLY

In the process of transpiration, forest vegetation withdraws large amounts of water from the soil which passes through trees and plants and is released into the air. The canopy of forest vegetation also intercepts water and snow and some of this also evaporates directly into the air. In some forested watersheds of the eastern United States, as much as half of the annual precipitation is returned to the air as a result of evaporation and transpiration and never reaches a ground water zone or stream (12).

Removal of forest trees from a hardwood watershed well stocked with trees will increase the yield of water

FIG. 8. *The grass shoulders of this logging road prevent erosion and provide food for game animals.*

THE HYDROLOGICAL CYCLE

in summer measured by streamflow. The increase is related to the amount of vegetation removed (16). Light selection cutting (removal of only a few trees), has no appreciable effect on water flow, while complete clearcutting may increase the yield very substantially for several years. In one eastern U.S. experiment, killing all forest vegetation to eliminate transpiration increased streamflow up to five times during normally low flow periods (15). As forest re-growth takes place, streamflow again decreases. Managing forests (although not necessarily by clearcutting) to increase water yield for municipal, recreational, agricultural, industrial and other uses is likely to become of increasing importance in the future.

EFFECTS ON SEDIMENTATION

Forests can have a marked effect on the amount, accumulation rate and type of sedimentation of streams. This is indicated in a study of a mixed-land use watershed in Michigan in which rates of sedimentation from land in different uses were compared (19). The average sedimentation yield rate as measured in pounds/day/square mile was 2,200 from cultivated land, 1,800 from pasture land, 360 from forest land and 74 from wild land (swamps, bogs, brush land, and idle land). Sedimentation of water basins is similarly affected by land use. Whenever a forested watershed is urbanized or put into farm use, an increase in sedimentation of water basins can be expected (13).

EFFECTS ON FLOODING

The effect of forests on floods is uncertain since rapid runoff cannot be prevented when the forest floor is already saturated or frozen. However, the forest floor is likely to be open to some percolation when the surface of open fields is frozen solidly, and snow accumulation in the forest remains longer than in nearby exposed areas. In general, forests tend to reduce flood flow in small watersheds in hilly country. The effect of this on flood flow in larger river systems is more uncertain since the timing of peak flows from tributaries and their cumulative effect on peak flows in the main river may or may not be helped by forest conditions.

BIBLIOGRAPHY

1. American Chemical Society. 1969.
Cleaning Our Environment —
The Chemical Basis for Action.
Amer. Chem. Soc., Wash., D.C. p. 41.

2. Bates, Carlos G. 1924.
The Windbreak as a Farm Asset
USDA Farmers' Bull. No. 1405 (Rev. 1944). 22 pp.

3. Buck, Charles C. (compiler). 1964.
Winds over Wildlands —
A Guide for Forest Management.
USDA For. Ser., Agr. Handbook No. 272. 32 pp.

4. Bormann, F. H., G. E. Likens and J. S. Eaton. 1969.
Biotic Regulation of Particulate and Solution Losses from a Forest Eco-system.
Biosci. 19:600-610.

5. Dockinger, Leon S. 1970
The Impact of Air Pollution on Christmas Tree Plantings.
Amer. Forests 14 (3):5-8.

6. Ferber, Arthur E. 1969.
Windbreaks for Conservation.
USDA Soil Conser. Ser., Agr. Info. Bull. 339. 30 pp.

7. Hornbeck, J. W. 1968.
Protecting Water Quality During and After Clearcutting.
J. Soil and Water Conser. 23(1):19-20.

8. Jacobson, Jay S. and A. Clyde Hill (editors). 1970.
Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas.
Informative Report No. 1, TR-7 Agr. Committee, Air Pollution Control Assoc., Pittsburgh, Pa. 52 pp.

9. Kochenderier, James N. 1970.
Erosion Control on Logging Roads in the Appalachians.
USDA For. Ser. Res. Paper NE-158. 28 pp.

10. Leonard, Raymond E. and Sally B. Parr. 1970.
Trees as a Sound Barrier.
J. Forestry 68(5):282-283.

11. Lull, Howard W. 1959.
Humus Depth in the Northeast.
J. Forestry 57:905-909.

12. Lull, Howard W. 1967.
Increasing Water Yield in the Northeast by Management of Forested Watersheds.
USDA For. Ser. Res. Paper. NE-66. 45 pp.

13. Lull, Howard W. and William E. Sopper. 1969.
Hydrologic Effects from Urbanization of Forested Watersheds in the Northeast.
USDA For. Ser. Res. Paper NE-146. 31 pp.

14. Miller, Paul R. 1969.
Air Pollution and the Forests of California.
Calif. Air Envir., U. of C., Riverside, Calif. 1(4):1-3.

15. Pierce, Robert S. 1969.
Forest Transpiration Reduced by Clearcutting and Chemical Treatment.
NE. Weed contr. Conf. Proc. 23:344-350.

16. Reinhart, K. G., A.R. Eschner and G. R. Trimble, Jr. 1963.
Effects on Streamflow of Four Forest Practices in the Mountains of West Virginia.
USDA For. Ser. Res. Paper NE-1. 79 pp.

17. Rutherford, William, Jr. and Elwood L. Shafer, Jr. 1969.
Selection Cuts Increase Natural Beauty in Two Adirondack Forest Stands.
J. Forestry 67:415-419.

18. Smith, Frederick E. 1970.
Ecological Demand and Environmental Response.
J. Forestry 68:752-755.

19. Striffler, W. David. 1964.
Sediment, Streamflow, and Land-use Relationships in Northern Lower Michigan.
USDA For. Ser. Res. Paper LS-16. 12 pp.

20. Treshow, Michael. 1970.
Environment and Plant Response.
McGraw-Hill Book Co., New York. pp. 245-376.