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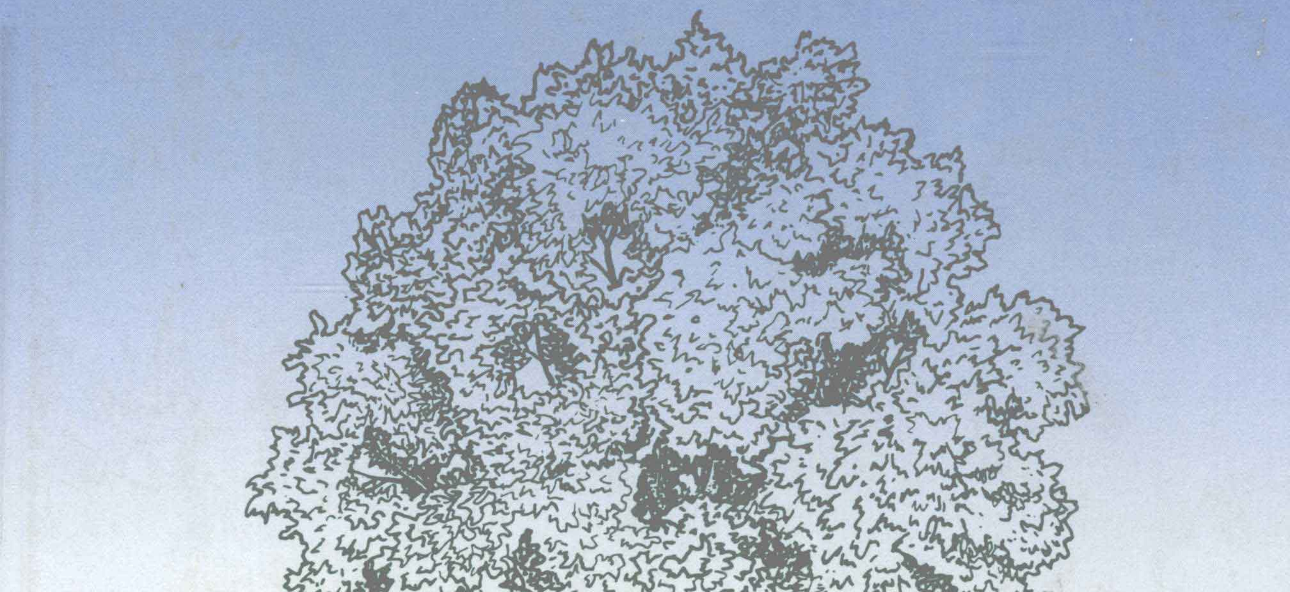
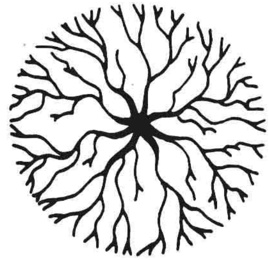
ARBORICULTURE

INTEGRATED MANAGEMENT OF LANDSCAPE TREES, SHRUBS, AND VINES



RICHARD W. HARRIS

SECOND EDITION



ARBORICULTURE

Integrated Management of Landscape Trees, Shrubs, and Vines

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Preface

Research findings, application of research information, innovative ideas of practitioners, new and improved equipment and products, and a better informed and more concerned public bode well for the future of arboriculture. The revision of *Arboriculture* attempts to evaluate new information and maintenance practices and, where appropriate, to reassess current practices in light of new information.

Improved approaches to integrated pest management have dramatically demonstrated the interrelatedness of maintenance practices and physical, chemical, and biological environment to a plant's health and well being. The subtitle of the book has been changed to reflect the opportunity and the need to integrate the management of landscape plants. The aim of this book is to increase understanding of plants and plant processes, to improve the ability of horticulturists to analyze problems and practices, and to help them more effectively integrate the management of the environment and maintenance of landscape plants.

The common and botanical names used in this book generally conform to those listed in *Hortus Third* (Bailey and others 1976) and the *Annotated Checklist of Woody Ornamental Plants of California, Oregon, and Washington* (McClintock and Leiser 1979).

Measurements are given in metric units, followed by nonmetric equivalents in parentheses. In many situations, approximate values are accurate enough, so conversions between the two systems are rounded for simplicity.

Certain statements in the text are printed in boldface in order to emphasize their importance.

Due to space limitations, certain topics are only briefly discussed in this edition; some were covered in more detail in the first edition. These topics are printed in boldface in the index so that you can refer to the first edition should you wish to pursue the subject further.

The last five years have been extremely interesting and challenging as I reviewed literature, attended meetings, and talked with researchers and others involved in landscape planning and maintenance. Even more rewarding was the exhilarating feeling experienced from the warmth and generosity of researchers and practioners in sharing photographs, ideas, and expertise. I am greatly indebted to many, many people, some of whom are credited in the text for supplying illustrations, photographs, and information new to me.

As in the first edition, I am deeply indebted to my wife, Vera, for her patience and understanding, for her help in preliminary and proof editing, and for her skill as an illustrator.

In addition to the many who helped with the first edition, the following were particularly helpful with this revision. Colleagues generously assisted by sharing their experience and in many cases for reviewing portions of the manuscript. These include Kevin L. Blaze, Victoria College of Agriculture and Horticulture, Australia; James R. Clark, University of Washington; Henry Donselman, Rancho Soledad Nurseries, Rancho Santa Fe, CA; James R. Feucht, Colorado State University; Edward F. Gilman, University of Florida; Jitze Kopinga, Research Institute for Forestry and Landscape Planning, Wageningen, The Netherlands; Glen P. Lumis, University of Guelph, Canada; Dan Neely, University of Illinois; Derek Patch, Forestry Commission Research Station, Farnham, England; Thomas O. Perry, University of North Carolina; Michael J. Raupp, University of Maryland; Frederick Roth, California State Polytechnic University, Pomona; Alex L. Shigo, Shigo and Trees, Associates, Durham, NH; and Gary W. Watson, The Morton Arboretum, Lisle, IL.

Among colleagues of the University of California who helped, I am particularly indebted to Arthur H. McCain at Berkeley; Alison M. Berry, David W. Burger, Steve H. Dreistadt, Clyde L. Elmore, Andrew T. Leiser, James D. MacDonald, Jack L. Paul, Roy M. Sachs, and Richard F. Walters at Davis; and Laurence R. Costello, W. Douglas Hamilton, and Pavel Svihra of the Cooperative Extension Service.

Firsthand experience and examples that have been useful were provided by many arborists, including Stephen Bakken, California Department of Parks and Recreation; John C. Britton, John Britton Tree Service, St. Helena, CA; Guido H. Ciardi, City of San Francisco; Steve Clark, SC&A, Brentwood, TN; Eugene Eyerly, Eyerly & Associates, Denver, CO; Niels Hvass, SITAS, Ballerup, Denmark; Richard A. Johnstone, Delmarva Power and Light Company, Salisbury, MD; Keith R. Jones, Central Illinois Public Service, Springfield; Gordon W. Mann, City of Redwood City, CA; Nelda Matheny, HortScience, Pleasanton, CA; John McNeary, McNeary Arborists, Charlotte, NC; Kenneth C. Meyer, Mayne Tree Expert Company, San Mateo, CA; Jack Siebenthaler, Consultant, Clearwater, FL; Robert W. Skiera, City of Milwaukee, WI; Michael W. Watson, Potomac Edison Company, Hagerstown, MD; and Richard H. Wells, Philadelphia Electric Company, PA.

Although I have been helped by many, I take full responsibility for the ideas presented, their interpretation, and their accuracy. Research, practices, and observations that postdate this book or that have escaped my attention may warrant modification of the recommendations or explanations that appear here. I would appreciate receiving such information so that all may benefit from the most current advances in the field.

I am particularly indebted to Linda Pawelchak for editing the manuscript, helping ideas flow logically, and ensuring accuracy of cross references. Joan L. Stone and Robin Baliszewski of Prentice Hall were extremely patient and helpful throughout the preparation of the book.

Richard W. Harris

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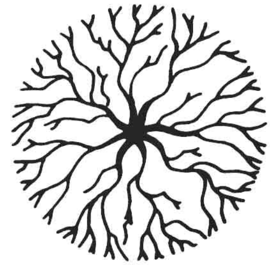
CHAPTER 1



Landscape Trees, Shrubs, and Vines

While plants contribute to our pleasure, comfort, and well-being, they also help conserve energy and the quality of air, water, and soil. Plants, particularly trees, are an important part of our lives—around homes, schools, shopping centers, and places of work, along streets and highways, in the central city, parks, and other landscaped areas.

Trees have been held in high esteem since earliest times. More than 4000 years ago, Egyptians wrote of trees being transplanted with a ball of soil around the roots of each (Chadwick 1971); some were moved 2400 km (1500 miles) by boat. In Greece, Theophrastus (370–285 B.C.) and Pliny (A.D. 23–79) gave rather complete directions for tree planting and care. Many books on the care of plants, including trees, have been written since these times.

In the Middle Ages, botanical gardens primarily contained plants that had medicinal potential. Later, the gardens of private estates boasted exotic plants brought in through trade and travel. Many of these gardens have since become public and are great sources of information and pleasure.

By the 1700s, trees were being planted with some frequency in the cities and estates of Europe. In the early settlements of North America, trees were cut to make room for farms and towns, but by the late 1700s, trees were being planted in town squares. After planting, however, few of these trees received much care, except on large estates. As settlers moved west onto the prairies, they planted the seeds of fruit and shelter trees around their homes.

In the early 1900s, national research agencies in Europe and North America and state agricultural experiment stations began to study fruit and forest trees. By the 1950s, state and national research stations had begun working specifically on landscape tree problems. The devastation caused by chestnut blight, Dutch elm disease, phloem necrosis, Gypsy moths (*Porthetria dispar*), and Japanese beetles (*Popillia japonica*) in the northeastern and midwestern United States was largely responsible for the increased interest in tree research, though this research consequently focused on disease and insect control. Experiment stations, botanical gardens, arboreta, and some large nurseries have long been involved in landscape plant introduction; increasing efforts have sought trees that will be better able to withstand the rigors of the urban environment.

Governmental agencies sponsor extensive parks and landscape tree plantings. Many cities require street-tree plantings in new residential and commercial developments. People are more aware of trees and their value. Many cities in the United States have ordinances controlling the removal of trees, even on private property. One of the stipulations of England's Civic Amenities Act of 1967 addresses the preservation and planting of trees on private property (Chadwick 1971).

Several professional organizations are concerned with tree planting and care. The National Shade Tree Conference, organized in 1924 in Connecticut, later became the International Society of Arboriculture, with current headquarters in Urbana, Illinois. The Society has members on every continent except Antarctica. Other United States organizations include the National Arborists Association (commercial arborists), the Society of Municipal Arborists, and the American Society of Consulting Arborists. The Arboricultural Association in Great Britain is similar to the International Society of Arboriculture. Many other organizations are concerned with landscape trees; among them are the American Association of Botanic Gardens and Arboreta, the American Entomological Society, the American Forestry Association, the American Horticultural Society, the American Society for Horticultural Science, the American Society of Landscape Architects, the National Arbor Day Foundation, the Society of American Foresters, and the American Phytopathological Society.

Many technical schools, colleges, and universities offer courses in arboriculture, landscape horticulture, and urban forestry, with supporting courses in botany, entomology, plant pathology, landscape design, and soils.

ARBORICULTURE

Arboriculture, as herein defined, is primarily concerned with the planting and care of trees and more peripherally concerned with shrubs and woody vines and groundcover plants. Arboriculture is commonly defined as the cultivation of trees and shrubs only (Bailey and others 1976, *Webster* 1976), but woody plants that are called *vines* in the United States are called *wall shrubs* in England (Brown 1972, Halliwell, Turpin, and Wright 1979) and *climbing shrubs* in Australia (Mullins 1979). It seems reasonable to assume that the common definition of arboriculture includes woody vines. All of the plants mentioned are woody, perennial plants that have many common needs and characteristics and differ primarily in their form and training requirements. Even so, a wisteria vine can be trained into a tree, and the mature form of English ivy is shrub-like (see Fig. 2–18). *Hortus Third* (Bailey and others 1976) further defines arboriculture as the cultivation of plants as individuals rather than as elements in a forest or orchard.

Arboriculture is one of the branches of horticulture within the plant sciences. Following are the fields within plant science, their definitions, and their relationships to one another.

Plant Science
- *Agronomy* and *Range Science* deal primarily with the cultivation of field crops and range and pasture plants
- *Forestry* concerns the commercial production and utilization of timber
  - *Silviculture* is the practice of raising forests
  - *Urban Forestry* is the management of trees in urban areas on larger than an individual basis
- *Horticulture* concerns plants that are intensively grown for food and aesthetics
  - *Pomology* is the cultivation of perennial fruiting plants, primarily woody trees and vines
  - *Vegetable Crops* (Olericulture) is the growing of herbaceous plants for human consumption
  - *Environmental Horticulture* is the cultivation of plants to enhance our surroundings
    - *Floriculture* is the production of cut flowers and potted plants
    - *Nursery Production* (Ornamental Horticulture) is the production of primarily woody plants for landscape plantings and fruit production
    - *Landscape Horticulture* is the care of plants in the landscape
      - *Arboriculture* concerns the cultivation of woody plants, particularly trees
      - *Landscape Construction* involves the installation of structural and plant materials according to a landscape plan
      - *Landscape Maintenance* (*Gardening* or *Grounds Maintenance*) specializes in the planting and care of a wide variety of plants used in the landscape
      - *Turfgrass Culture* concerns the growing of turf for landscape and sports use (some consider it agronomic)
- *Landscape Architecture* concerns the planning and design of outdoor space for human use and enjoyment
- *Park Management* concerns the total responsibility of planning, developing, and managing public and private landscaped areas, from housing developments and city parks to heavily used national parks

Even though these areas of specialization are often thought to be mutually exclusive, the lines of demarcation between them have blurred. A company or agency may engage in landscape design, nursery production, and all phases of landscape horticulture. Another may specialize in one or two. Many organizations find that by engaging in more than one specialization, they are able to maintain a more stable labor force and to spread financial risks.

PLANTS IN THE LANDSCAPE

As public and private plantings become more common and more expensive to maintain, people responsible for such plantings are becoming more concerned about the proper selection and care of landscape plants. The landscape comprises a palette of plant growth habits: trees, shrubs, vines, grass, and herbaceous flowering and foliage plants. This book focuses on the selection and care of woody perennial plants, primarily trees, but also devotes some attention to shrubs, vines, and ground-cover plants (see Fig. 2–1). Perennial plants with these habits of growth have much in common as regards selection and care in the landscape. Because of the ultimate size and long life of trees, their proper selection and care is of greater importance. Woody plants respond much as trees do to most environmental conditions and cultural practices.

Plants not only provide food and fiber but enhance our surroundings in a variety of ways: physical, aesthetic, economic, and psychological. Some influences are important to our immediate surroundings; others are significant only on a more extensive scale. Cited most often when the value of landscape plantings is extolled are *physical* attributes: influence on climate, air purification, noise reduction, and erosion control. The microclimate can be greatly enhanced by plants, particularly trees, when they are properly selected, placed, and maintained.

PHYSICAL BENEFITS

Microclimate Enhancement

Plants absorb heat as they transpire, provide shade that reduces solar radiation and reflection (Fig. 1–1), can reduce or increase wind speed, and can increase fog precipitation and snow deposition. Trees are frequently called nature's air conditioners. A hectare (2.47 acres) of vegetation transpires about 17,000 liters (4000 gal) of water on a sunny summer day. Oke (1972) estimates that a 30 percent cover of vegetation will give two-thirds as much cooling as will a complete plant cover. Thus, in a 0.08

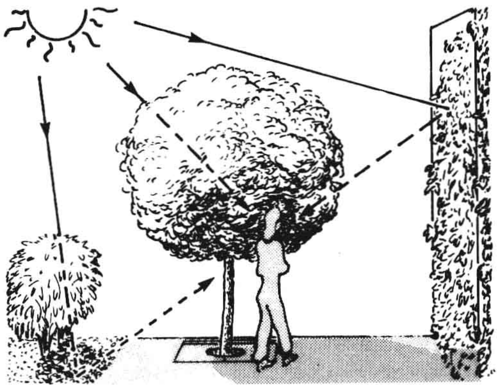


Figure 1–1 In summer, plants provide comfortable surroundings by intercepting direct solar radiation and reradiation from heated surfaces. (Adapted from Robinette 1972)

hectare (one-fifth acre) lot with 30 percent plant cover, transpiration would absorb 1.2 million kilogram-calories of energy that would otherwise warm the environment. That is equivalent to the amount of cooling necessary to air condition two moderately sized houses 12 hours a day in the summer.

This evaporative cooling, however, is quickly diffused so that even on a hot summer day, the air temperature of an area of plants is not much lower than that of an area with few or no plants. Herrington, Bertolin, and Leonard (1972) found that shaded sites in a 30-hectare (75-acre) park in Syracuse, New York, averaged only 1.3° C (2.5° F) cooler than urban sites outside the park, even though solar radiation under the trees was only one-fourth of that in the urban sites. Temperatures outside the park would certainly have been higher had the park and other vegetation not been there, since temperature differences are evened out fairly effectively by air movement and diffusion. Fortunately, thermal comfort results from the interaction of the human body with a number of factors in the environment, including air temperature, relative humidity, wind speed, solar radiation, and infrared radiation. **The most important influence of trees on the microclimate is their control of solar radiation in both winter and summer.**

Trees minimize heat reflection and reradiation by shading pavement and buildings and by reducing direct rays of the sun (Fig. 1–1). Shade from trees can reduce room temperatures in poorly insulated houses by as much as 11° C (20° F) in summer (Deering 1955). Deering and Brooks (1953) found that bare-ground surface temperatures of 56° to 67° C (130°–150° F) were cooled an average of 20° C (35° F) in five minutes after being shaded. Any barefoot youngster knows the value of shade on a summer afternoon. In Memphis, Tennessee, Dunn (1975) found that property owners, in appraising the value of a tree, were able to use the cost of constructing a structure that would provide equivalent shade, and they had not been successfully challenged by the U.S. Internal Revenue Service. At the time, a modest sturdy structure would have placed the value of a shade tree at \$27.50 to \$33.00 per square meter (\$2.50–\$3.00/ft^2) of shade. In the tropics, evergreen trees provide year-round protection from the sun. In temperate regions, deciduous trees provide summer shade and permit the winter sun to warm the ground, although the sun can be considerably impeded: Light intensity under dormant trees is reduced 20 to 74 percent (Geiger 1961). Unless properly sited in temperate regions, deciduous trees can intercept enough sunlight to increase winter-heating costs more than they decrease summer-cooling costs of solar and most conventional houses (see Chapter 5) (Thayer 1986a).

Plants modify wind by obstructing, guiding, deflecting, and filtering air flow (Robinette 1972). Air movement influences real and perceived temperatures; for example, with a chill factor of 30 kmph (20 mph), a wintry blast of 0° C (32° F) air will cool as if it were −14° C (7° F). Windbreak and shelterbelt plantings shelter smaller plants, animals, and property by reducing wind speed on both the windward and leeward sides (Geiger 1961). Nearby shrubs help protect buildings from the cold by reducing radiation loss and providing an insulating zone of relatively still air. A dense planting across a slope can create a frost pocket on its uphill side, however, by slowing the downward flow of cold night air (Fig. 4–3).

Plants, by their form and placement, can guide or funnel wind through openings or over their tops and in so doing can increase wind speeds by as much as 20 percent (Robinette 1972). A row of trees with dense heads can create quite a wind tunnel between the ground and the lowest branches.

Trees in particular can reduce fog density by condensing moisture on leaf and twig surfaces. Geiger (1961) reported that woods along the coasts of Japan protect inland areas from fog; six to ten times as much moisture was deposited under trees as on nearby open grassland. Similarly, the windward edge of a woods had 20 times as much fog precipitation as did the lee side. The summer fogs common in many coastal sites greatly influence the moisture economy of these areas. Not only does summer fog reduce evapotranspiration, but fog precipitation can account for 20 percent of the annual precipitation in wooded areas (Geiger 1961).

By slowing air, a windbreak with a density of 50 percent can quite effectively cause snow to accumulate in front of, within, and behind the barrier. Conversely, plantings that channel air flow will keep the areas of increased wind relatively free of snow and other airborne particles.

Air Purification

In many urban areas, the concentrations of air pollutants are so great that plants are not able to grow at their best, much less reduce pollution to acceptable levels. Air currents and the diverse sources of contaminants make air pollution a regional concern. The major effort must be to reduce emissions from vehicular and industrial sources (Schmid 1975). When air pollutants are at reasonably low levels, plants will be healthier, more active, and more effective in further reducing air impurities. Schmid found that ozone concentrations were reduced several times faster during the day when plants were transpiring rapidly (stomates open) than at night, when transpiration was low.

Gaseous pollutants are absorbed into active plant tissue, primarily within leaves, and are adsorbed on plant surfaces. Lanphear (1971) estimated that 50 million Douglas fir trees 300 mm (1 ft) in trunk diameter would be required to mitigate the 410,000 metric tons (452,000 tons) of sulfur dioxide released each year in St. Louis. That many trees would cover about 5 percent of the city's land surface. Bernatzky (1978), however, cites two German reports of deciduous forests having no perceptible sulfur dioxide filter effect compared with coniferous forests. In addition, many of the gaseous pollutants are exhausted or rise above even the tallest trees. Little sulfur dioxide released in a city remains there to be absorbed by trees (Bernatzky 1978, see Chapter 20).

Even though plants absorb carbon dioxide from the air and release oxygen, plants in a city have little effect on carbon dioxide and oxygen levels there. In fact, Weidensaul (1973) states that "It is not accurate to say that [land] plants really play a significant role in maintaining the concentration of oxygen and carbon dioxide in the atmosphere." Photosynthesis in the oceans supplies 70 percent (Cole 1968) to 90 percent (Bonner and Galston 1952) of the world's total oxygen. Winds and convection currents help maintain these gases at fairly uniform levels. **Protecting oceans from pollution is indeed critical to preserving a viable CO_2–O_2 exchange.**

Even though the world's oxygen supply is exceedingly large and well buffered

(Broecker 1970), a slight reduction in the level of oxygen could result in a sizeable percentage increase in carbon dioxide. Carbon dioxide and other gases in the atmosphere intensify the so-called ''greenhouse'' effect which would tend to increase the earth's temperature. Most all-natural systems, however, are well buffered. For example, should the earth warm, more moisture vaporizes from the oceans forming clouds which in turn reduce the amount of sunlight (Cosgrove 1989). This is a simplistic example but illustrates the point. This is not to imply plants are of little value in maintaining our environment, but to caution against over reaction.

Vegetation ameliorates air pollution most effectively through its ability to reduce airborne particulates. This is primarily a windbreak effect, reducing wind speed so that heavier particles settle out. In addition, particles are adsorbed on plant surfaces, primarily the leaves. Evergreens are recommended for this purpose since they are equally effective the year around. Foliage can become so coated, however, particularly along highways, that it must be spray-washed for both health and appearance. Bernatzky (1978) reports that in Frankfurt/Main streets with trees had 3000 particles per liter of air, compared with 10,000 to 12,000 in streets without trees.

Plants also reduce the content of heavy metals polluting air. Summarizing several studies, Schmid (1975) estimates that in Connecticut, one sugar maple tree of 300 mm (1 ft) trunk diameter at 1.4 m (4.5 ft) above the ground removes from the air in one growing season 60 mg of cadmium, 140 mg of chromium, 820 mg of nickel, and 5200 mg of lead. He further states that lead concentrations in plants taper off quickly with distance from major highways. In spite of the several ways that plants reduce air pollution, their presence near polluting sources is not generally considered to be of particular importance to urban air quality (Schmid 1975).

Noise Reduction

Plants are not very effective in reducing noise. ''Out of sight, out of mind'' applies somewhat and may be of importance in confined spaces. However, **in order to reduce noise levels appreciably, plantings must be dense, tall, and wide** (25–35 m; 80–115 ft) (Fig. 1–2). Plantings close to the noise source are more effective than similar plantings further from the source. Fleshly leaves and numerous branches increase excess attenuation; that is, they reduce (attenuate) noise more than simple distance will. Most species, however, do not differ greatly in their ability to reduce noise

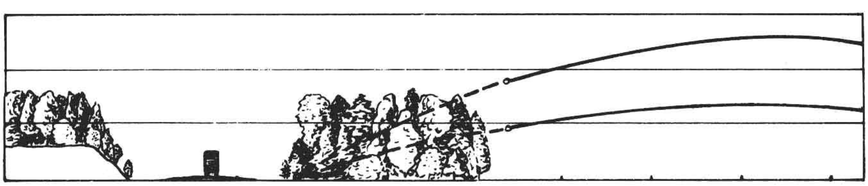


Figure 1–2 Thirty meters (100 ft) of trees and shrubs reduce truck noise about as effectively as would a similar area of bare cultivated ground. (Cook and Van Haverbeke 1971)