WOODY FIBER FARMING: AN ECOLOGICALLY SOUND AND PRODUCTIVE USE OF RIGHTS-OF-WAY

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The transportation and transmission systems in the United States are estimated to have more than 22 million acres of rights-of-way of which approximately 6 million acres are forest land. The present annual national maintenance cost for mowing, cutting, burning, and spraying is estimated to be at least $200 million, an amount that increases each year. The serious national concern about air and water pollution has already encouraged some voluntary and some legislative action to eliminate burning and spraying. In the absence of these techniques, maintenance costs are increased by a factor of five, and the future annual maintenance bill may be $1 billion if all burning and chemical spraying are stopped. Biomass, nutrient, and pulping studies led to the Complete Tree Concept in 1964. An evolution of this concept is the production and utilization of the currently noncommercial tree and shrub species, commonly called "puckerbrush," that occur on rights-of-way. These species will produce useful paper and paperboard products in less pulping time than commercial tree species. Because "puckerbrush" is not large, 10 to 30 ft in height, and because there are many stems per acre, special harvesting equipment must be developed. Naturally occurring "puckerbrush" on rights-of-way can be harvested in 10- to 15-year cycles. Growth can be augmented by use of fertilizers and by deliberately developing genetically superior species. Thus, it should be possible to derive from the management of rights-of-way on forested land a net profit that will drastically reduce the overall right-of-way maintenance cost.

•THE land area of the United States including Alaska and Hawaii has been 3,548,974 square miles (16) or 2,271,340,000 acres for at least 400 years. The natural forest area once was approximately half of the total land area, but this has been reduced to 759,000,000 acres, about one-third, because of agriculture, urban development, and transportation and utilities rights-of-way. As the population in our country increases, there will inevitably be fewer forested acres. It is appropriate now for us to consider a basic question: Does man need forests and if so to what extent?

In the photosynthetic process, green plants synthesize carbon dioxide and water into carbohydrates in the presence of light. Oxygen is produced as a by-product that enters the atmosphere. Man requires oxygen to live, and it is extremely doubtful that he could live in the total absence of green plants.

There are three other major uses of the forest by man. One is watershed management for the retention and distribution of water for drinking and other purposes. The second is recreation, which is becoming increasingly important to people who live in cities. The third is as the source of wood for solid products such as lumber and railroad ties and reconstituted products such as paper and paperboard, particle board, and fiber board. No one now knows how much forest land is essential per person to meet the four major human demands on the forest.

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It is possible to forecast future wood requirements. Duerr (2) has depicted these requirements in Figure 1, which shows an overall increase in the use of wood, an increase in the proportional number of reconstituted products, and a decrease in the per capita consumption of wood. Unhappily, we cannot forecast in a quantitative manner the increasing demands for oxygen, water, and recreation in the forests. The demand will be proportional to the increase in population, but the effect on the forest may be much greater. It is safe to state that the four major uses of the forest by man are exerting pressure and that the pressure will continue to increase unless some direct action is taken to reduce it.

The exact acreage of transportation and utilities rights-of-way is not known. Estimates (1) are given in Table 1. The Maine State Highway Commission (3) has estimated that the rights-of-way on rural roads in Maine (exclusive of roadway) take up approximately 95,000 acres on 21,340 miles of road. By extrapolating this limited information to the U.S. rural road network and by incorporating the national proportion of forested lands, the Commission made estimates of the rights-of-way acreage extending through forested land. These rights-of-way are currently maintained by planting and mowing grass, by cutting and burning woody vegetation, or by periodically spraying chemicals to destroy the wood vegetation.

The Maine State Highway Commission has voluntarily banned brush burning, and the legislature of Vermont has made illegal the chemical spraying of brush. It is entirely possible that legislative action in other states will follow along similar lines. Maintenance costs appear to increase by a factor of five when burning and spraying are prohibited. If the nation continues to exert pressure on all forms of pollution, the annual right-of-way maintenance cost could reach the $1 billion level within a decade.

This paper will present a method whereby the cost of right-of-way maintenance can be drastically reduced without polluting the environment. Simultaneous pressure on the forests will be reduced by providing an alternative source of raw material for reconstituted woody fiber products.

DEVELOPMENT AND EVOLUTION OF THE COMPLETE TREE CONCEPT

Pulping, biomass, and nutrient studies were initiated in 1959. By 1964 the Complete Tree Concept (9) had crystallized based on the available data. This is a biological concept and consists of technological investigation of the entire tree from the root hairs to the leaf hairs. This is in sharp contrast to the concept of the merchantable bole, which is currently in vogue. A series of papers and bulletins (3, 4, 6, 9-15) show the following:

1. Regardless of size or species, the distribution of wood fiber is approximately as follows: bole (65 percent), unmerchantable top (5 percent), branches (5 percent), stump (15 percent), and roots (10 percent) as shown in Figure 2;
2. Approximately half of the 15 essential elements in a tree are in the merchantable bole with about half in the wood and the remainder in the bark;
3. Pulp made from the wood of the logging residue is similar in yield and physical properties to pulp made from the wood of the merchantable bole except for the branches, which have a lower yield and poorer physical characteristic;
4. Use of all of the logging residue would increase yield from the forest by 50 percent.

The merchantable bole is commonly measured in board feet or cords, two units of cubic measurement. The varied size, shape, and abundance of branches and roots made it impractical to use volume as the measuring unit because of the time and errors in volume determination. It was preferable to use weight in the complete tree studies because of its simplicity, it rapidity, and the limited sources of error. Despite the fact that only mature trees were used in the initial study, all of the tree components were measured in the same unit: weight. With attention focused on the Complete Tree Concept rather than only the merchantable bole, it was possible and reasonable to look at the forest from a much broader perspective. The Complete Tree Concept led to an

Figure 1. Consumption of wood products in the United States, 1900 to 2000: 13-year moving average quantities expressed in terms of roundwood equivalents, including both domestic and imported wood.

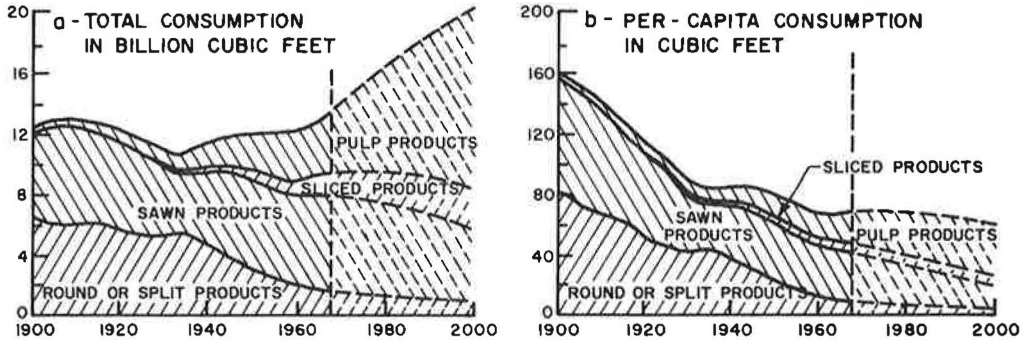
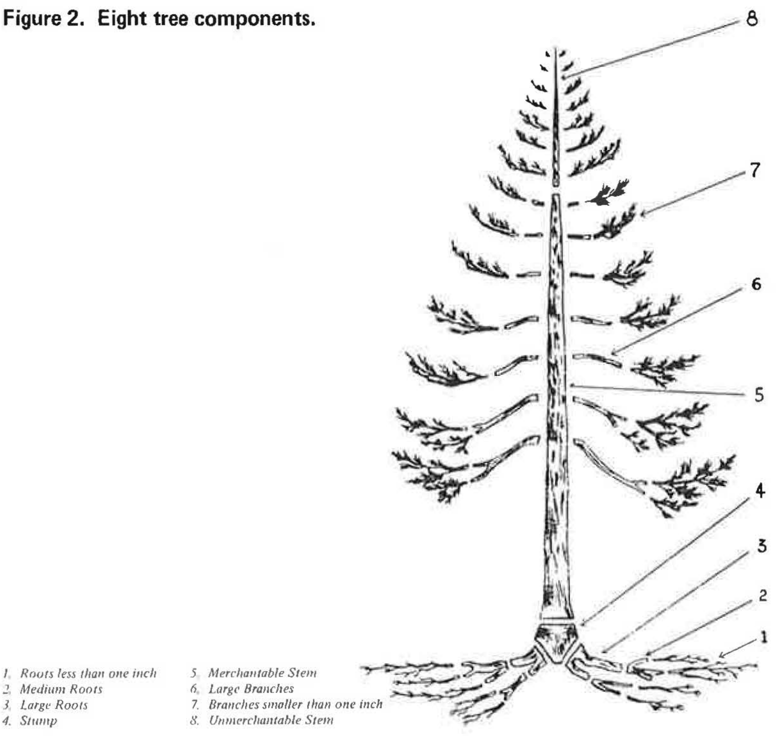


Table 1. Rights-of-way estimates for the United States.

Right-of-Way	Miles	Total Acreage	Forested Acres
Rural roads	3,152,047	15,000,000	3,700,000
Power transmission	300,000	4,000,000	1,300,000
Railroads	208,111	3,300,000	800,000
Total	3,660,158	22,300,000	5,800,000

Figure 2. Eight tree components.



examination of the entire standing crop of trees, which encouraged consideration of dry matter production per acre in much the same manner as agricultural specialists think about wheat, corn, and other crops.

Regeneration for the next crop is obtained in present forest management in one of two ways. One is by deliberately leaving a few or many seed trees and the other by clear cutting and planting. The former is by far the dominant method on a worldwide basis. From the perspective of the Complete Tree Concept, both methods leave much to be desired. In the selective logging method, many small trees are incidentally destroyed; in the clear cutting method, all trees not immediately harvested are deliberately destroyed prior to planting. Studies of the smaller trees and shrubs (15, 16) led to the Complete Forest Concept in 1967. This is a biological concept and includes a technological study of all of the woody shrubs and trees with a view to intensive management of selected areas.

Up to this point, the major thrust of the research has been with seedlings, saplings, and mature specimens of commerical tree species. Only minor effort has been expanded on woody shrubs. In other words, no attention had been placed on noncommercial trees and shrubs. In Maine there are more than 50 species of noncommercial hardwood tree and shrub species. These commonly grow in dense stands with literally thousands of stems per acre and are commonly called "puckerbrush." Inasmuch as "the bush" is a common term for commercial forests in several countries, the term puckerbrush can be applied equally as well to currently noncommercial tree and shrub species, which occur as successional species on every continent.

WOODY FIBER PRODUCTION AND UTILIZATION CONCEPT

The Complete Tree Concept was based primarily on studies of mature specimens of climax forest species. Because forest management and forest industries are based on the Merchantable Bole Concept, a considerable amount of knowledge has accumulated of such species. The Woody Fiber Production and Utilization Concept is simply the notion of utilizing all woody shrub and tree species regardless of size. This includes all of the currently noncommercial trees and shrubs in the successional stages as well as those currently recognized as being of commercial importance. Because of the current and past indifference to the potential usefulness of "puckerbrush," our knowledge of this species is extremely limited.

The serious study of "puckerbrush" within the Woody Fiber Production and Utilization Concept raises many questions. How rapidly does each species grow, and how does the overall growth compare with commercial species? What is the inventory of such species? What products can be made from such species? How can such species be harvested, and would the harvest cost be economically acceptable? How will "puckerbrush" fit into our economy, and what impact will its use have on our natural resources?

The Complete Tree Concept was publicly unveiled in 1964. Serious response took place in Canada (1967), the United States (1968), and Finland (1969) in major forest products laboratories. It now appears that the cooperative effort of the Finnish Forest Research Institute and a number of Finnish pulp and paper companies will be the first to bring this concept into reality by 1973. The Woody Fiber Production and Utilization Concept was publicly announced in 1970.

WOODY FIBER FARMING

Woody fiber farming, the practical application of the Woody Fiber Production and Utilization Concept, can be accomplished by two different approaches. One, the method of opportunity, is to harvest "puckerbrush" stands that have grown in naturally on abandoned fields, burned-over areas, or cutover areas with the intent of harvesting every 10 to 15 years. The other, the plantation or seeding method, is based on distributing genetically superior seed or planting genetically superior stock on rights-of-way. The intent here would be to harvest the succeeding coppice stands on a 10- to 15-year cycle. The first method requires no investment in the crop and consequently should not have as high a yield. The second method requires an investment initially in research followed by the cost of seed orchards or nurseries; however, in return it should provide higher yields that more than cover the added cost. The discussion that follows is directed at the plantation and seeding method.

Current right-of-way maintenance methods in forested areas eliminate woody vegetation by cutting and burning brush or by spraying chemicals. Both methods work, but they are costly and will continue to increase in cost as wages increase. If neither of these expensive methods was used, natural vegetation would grow and would pass through the successional stages until the climax forest was achieved, which would be undesirable to the right-of-way owner. By using 10- to 15-year periodic harvests, we could maintain the woody vegetation in a successional stage. The natural-occurring woody vegetation might not be fully stocked, might not be the most desirable species, and might not grow rapidly, but fertilization would increase annual dry matter production. Seeding with genetically superior seed or planting with genetically superior stock appears to be the best way to ensure fully stocked stands that will produce the maximum fiber per acre per year. The seeded or planted stock would regenerate and, after several cycles, would have to be supplemented by additional planting or seeding.

In Maine, "puckerbrush" (17) is producing about 1.2 tons of dry matter on the above-ground portion per acre per year, exclusive of the leaves. By using fertilization and plant improvement practices, we might develop fully stocked stands that would produce 5.0 tons of dry matter on the above-ground portion (exclusive of the leaves). Research will determine the maximum and economic optimum amount that can be grown.

Appropriate questions at this point are as follows: What will it cost to harvest "puckerbrush"? What will transportation costs be? What are the expected prices for "puckerbrush" delivered to the mill? Will pulp mills use such material? There are no established anwers available. Morbark Industries has recently made several tests (25,000 tons of chipped material per test). They estimate that the cost of green chips delivered a distance of 50 miles would be $4.87 per ton including stumpage of $0.50 per ton and all depreciation, maintenance, and labor costs. It will take at least two green tons of chips to be the equivalent of a cord, which would be competitive with hardwood cordwood delivered to the mill.

A considerable amount of work is under way to determine the quality of products that can be produced from "puckerbrush." Professor Chase has demonstrated in the laboratory that usable paper products can be made from "puckerbrush." At least one paper company (5) is making similar tests on a pilot plant scale using wood and bark from both small and large hardwood trees. Several other companies have indicated that they have been conducting laboratory studies. It appears that the problem is centered on the cooking conditions and amounts of chemicals to be used rather than the need to use new equipment.

Successful woody fiber farming of rights-of-way should markedly change maintenance costs. Woody fiber farming should result in a small net profit per acre in place of the $100 to $200 per acre costs for cutting and burning or spraying. Some areas will be unsuitable for woody fiber farming, and methods now in use will be continued as a direct cost. The net effect of woody fiber farming of rights-of-way should be a drastic reduction in overall maintenance costs, a considerable reduction in pollution, and the establishment of an additional source of raw material to meet the rapidly rising demand for wood products. Another potential advantage of fiber farming is in the area of safety. When an automobile leaves the highway at a high speed, the trees and shrubs should have a braking effect in contrast to the skidding action on grass.

There are two distinct types of research personnel working separately on complete tree utilization and biomass of complete trees and shrubs for ecological purposes. It appears that there are five major aspects of woody fiber farming that should be investigated by both types of researchers:

1. Utilization studies: for all reconstituted products that are currently on the market plus novel possibilities such as insulation material;
2. Biomass studies: there are many species, and very little work has been done to date;

3. Plantation and species improvement studies: these will require more time than the other aspects but will determine the maximum potential about species for which little is currently known;

4. Economic studies: sufficient biological and technological information is available for objective economic evaluation; and

5. Engineering studies: feasibility studies should be made followed by the development of prototype "puckerbrush" harvesters and complete tree harvesters.

With sufficient funds, staff, and equipment, all but the plantation and species improvement studies could be completed within a 5-year period for an extensive region. The plantation and tree improvement studies would take at least 15 years and possibly longer because woody vegetation does not produce during the first season.

For those who think only in terms of eliminating vegetation on rights-of-way, woody fiber farming must seem like an impossible dream. There are no biological or technological barriers, and, if the sociological barrier could be overcome quickly, woody fiber farming could become a reality by 1977 or earlier.

SUMMARY AND CONCLUSIONS

Biomass, nutrient, and pulping studies performed over a 12-year period led to the Complete Tree Concept, which evolved into the Complete Forest Concept and more recently the Woody Fiber Production and Utilization Concept. The latter is based on the use of successional species of trees and shrubs called "puckerbrush" in Maine which are not of commerical value today.

Woody fiber farming of rights-of-way is a practical application of the Woody Fiber Production and Utilization Concept. It will eliminate brush cutting and burning and brush spraying, two sources of pollution, and simultaneously provide an alternative source of raw material for mills making reconstituted products from wood. This should yield a small net profit for rights-of-way (specifically in fiber farming) and thereby dramatically reduce the overall maintenance costs, which will include a high percentage of rights-of-way that cannot be fiber farmed.

Woody fiber farming is only an idea in 1972, but it is based on considerable research. It can become reality by 1977 if sufficient funds are made available to do the necessary work in the engineering, economic, utilization, biomass, and tree improvements phases of the overall research.

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DISCUSSION

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Harold Young's paper deserves consideration as a serious proposal for the multiple use of transportation rights-of-way. One of the more sensible trends in recent years has been the acceptance of the fact that there is merit in utilizing transportation rights-of-way for various other constructive purposes that are compatible with the primary transportation function.

Apart from economic considerations, which could be of considerable importance in some instances, one could classify a proposed multiple usage as excellent, from a transportation functional perspective, if its net effect is to enhance or improve the transportation function; as acceptable if it neither enhances nor degrades the transportation function; and as undesirable if it has a distracting or degrading effect on the transportation function. Unfortunately, this classification cannot be made on a sweeping general basis but must be made on a finely subdivided station-to-station basis because a single proposed multiple usage might well be excellent at one station but highly undesirable at another.

I see Young's woody fiber farming usage as one that definitely falls into the latter category: excellent in some places, probably acceptable in many places, and highly undesirable in some other places.

Although at some time in the future it may become economically feasible to nurture and harvest small-stem brush for its woody fiber in certain adaptable highway right-of-way plots, there is nevertheless a greater immediate need for finding or developing the best species and then using them advantageously to enhance the transportation function as a permanent part of the right-of-way environment. A few of the more advantageous locations for permanent stands of relatively small-stem brush are as follows:

1. In the median strips of divided highways to screen headlight glare and to serve as a resilient median barrier to prevent cross-median accidents and to safely decelerate vehicles that wander into the median strip.
2. Beyond the roadway at the starting point of a horizontal curve. Even a relatively unalert driver who sees a thicket of brush straight ahead is likely to deduce that he will need to make a turn soon to avoid ending up in the brush thicket. If the driver does miss the turn and runs off the road, he still has a pretty good chance of surviving as he plows through several yards of nonrigid brush before coming to a relatively gentle stop.
3. As a crash cushion planted in front of rigid objects or other collision hazards located off the side of the road in places where there is room to plant enough brush for an effective crash cushion without creating other hazards. One could argue for a small-

stem brush crash cushion in almost any location where a driver might accidently run off the road.

4. As a screen planting for beautification purposes to hide junkyards and other roadside eyesores or to enhance an already pleasant view; also as a screen planting to screen the highway and its associated noise and glare from abutting or nearby property and to create a park-like environment to enhance the value of abutting property.

5. As a natural snow fence to force snow to drift into off-the-road areas instead of forming drifts on the roadway.

6. At incipient gully locations to inhibit gully scour that smaller vegetation might not be able to control and to prevent surface erosion on potentially unstable slopes.

7. As windbreaks in specific locations where sudden crosswinds catch drivers by surprise and cause accidents or serious driving tensions.

8. In wide rights-of-way, as wildlife habitat for numerous species of birds and small animals. Recent North Dakota studies have shown that managing rights-of-way as small game habitats does not create a significant accident problem.

9. Dense thorny brush thickets along right-of-way lines could eliminate the need for right-of-way fences in some locations.

This list is far from complete, and I may have overlooked some of the best reasons for desiring permanent stands of brush on highway rights-of-way, but it should at least serve to point out that small-stem brush does have a valid permanent role in comprehensive roadside management.

Unfortunately, stands of roadside brush may also have some very undesirable effects that are sometimes entirely incompatible with the primary transportation functions. Some of the more obvious negative factors are as follows:

1. Brush too close to the roadway will inevitably create some very dangerous sight-distance problems. Naturally occurring trees and shrubs on the convex side of horizontal curves must be removed or trimmed frequently to prevent the loss of safe sight distance. In my opinion, few maintenance organizations do an entirely satisfactory job of coping with this problem at the present time. Woody fiber farming simply could not be tolerated at any site where it might cause a loss of safe-passing sight distance or safe-stopping sight distance. Even on tangent sections of highway, it would be necessary to specify a rather generous minimum clearance distance between the shoulder and the "puckerbrush jungle" in order to give drivers a chance to avoid hitting any animal or person that suddenly emerges from the brush thicket and to prevent windstorms from blowing significant quantities of limbs or branches onto the roadway.

2. Brush should not be grown in locations where it would cause snow-removal problems or where it would form a natural snow fence that would cause snowdrifts to form on the highway or at locations where it would shade the highway and cause unexpected icy spots on the road. Autumn leaf fall could also create accident hazards at some sites.

3. It is virtually impossible to effectively remove the typical accumulation of roadside litter from a dense thicket of roadside brush. On the other hand, the brush would do a rather effective job of hiding some types of litter that could be "harvested" immediately after the harvesting of the brush for its woody fiber. Also, it is conceivable that public attitudes will change sufficiently to markedly reduce the amount of litter dumped on the roadside.

4. I worry that the "puckerbrush" stubble, following the wood fiber harvest, might well constitute an offensive eyesore that would be difficult to justify on the basis of a small woody fiber profit.

In view of the necessity to maintain a sizable brush-free strip on each side of the road for sight-distance safety reasons and because there will still be a need to pick up roadside litter, it is highly unlikely that woody fiber farming would reduce roadside maintenance costs by the amount that Young suggests.

To summarize my feelings on the matter, I see a lot of merit in growing small-stem brush species on transportation rights-of-way in places where this will improve the transportation function or enhance the value of the abutting property. In these cases, however, the brush should be maintained indefinitely instead of being periodically harvested. If we include areas on which a stand of brush would be incompatible with the transportation function, there still remain large portions of rights-of-way on which brush thickets could probably be grown and periodically harvested for their woody fiber without creating significant transportation or environmental problems.

I am not opposed to the proposal to grow small-stem brush on rights-of-way except in the incompatible locations mentioned earlier. I would be happy to see thickets of small-stem brush grown and maintained on transportation rights-of-way. If it ever becomes economically feasible to harvest these thickets, we can then worry about which thickets, if any, should be harvested and which ones should be permanently maintained.

AUTHOR'S CLOSURE

It was my pleasure a few years ago to visit the national monument near Kitty Hawk, North Carolina, where the Wright brothers achieved the first successful airplane flight. As I walked along the tiny track appropriately marked to show the distances of the first flights, I thought about their imagination, daring, and inventiveness as well as the myriad developments in the airplane since December 17, 1903. The Wright brothers did not believe that it would be possible to fly at night, and they did not foresee the impact of the airplane on civilization.

For woody fiber farming it is now, figuratively speaking, not 1903 but 1913. Insufficient research funds is the only factor that is preventing the full development of woody fiber farming.

Professor Scheer has admirably listed a number of likely advantages and disadvantages of woody fiber farming. Within a few years, I expect a few state highway commissions and electric transmission companies to try woody fiber farming on a small scale. As operational techniques are developed, confidence will be established and practical limits will come into focus. Then and only then will we really know the true relation between the sum total of the advantages and the sum total of the disadvantages.