Estimation of U.S. Bark Generation and Implications for Horticultural Industries[1]

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Abstract

The historical, current, and projected supply of bark was evaluated. Since the 1980s more than 95 percent of the U.S. bark supply has been utilized in some way. Industrial fuel consumes the largest share of the market for bark, absorbing about 83 percent of softwood bark and 66 to 71 percent of hardwood bark. Current market share of bark for horticulture use (categorized in the miscellaneous group), is about 15 percent of softwood bark supply and about 30 percent of hardwood bark supply. In recent years, domestic timber harvest has been relatively stable or has slightly decreased. During the same time period, there has been an increasing demand for bark as an energy resource. Based on historical data, linear models were fitted between U.S. timber harvest and bark generation at the regional level. With those fitted models, projected bark generation was estimated based on the timber harvest data of the fifth Renewable Resources Planning Act (RPA) timber assessment. It is estimated that only a minor increase in the long term bark output will occur. For softwood bark which has the greatest demand, projected supply will be below the level of 2001 until about 2020. With expected horticulture industry growth, increased value of bark as a readily available energy source for wood processing mills, and a shift in pulp generation from domestic paper mills to international sources, the total amount and share of bark to the horticulture market will likely decrease.

Index words: wood residue; substrate; mulch; compost; softwood.

Significance to the Nursery Industry

The concern over the availability of bark for horticultural use is not merely speculative. In the nursery industry, bark has been considered a resource instead of a waste since the 1970s. In recent years, with the continuous rise in energy prices, demand for bark as a clean fuel resource continues to increase. This increased demand for bark has coincided with the stable or slightly decreasing timber harvest since 1986; in the meantime, the horticulture industry has seen a rapid growth for the last two decades. With no significant decrease in current energy prices and only a minor increase in the long term bark output and expected horticulture industry growth, the market share of bark for horticultural usage will keep declining. Furthermore, regional shortages due to the closing of forest product mills will exacerbate the potential bark shortage. This analysis indicates that the demand for alternative substrates will continue to gain momentum in the near future.

Introduction

Bark, especially softwood bark, is widely used in horticulture as the primary component in most nursery and greenhouse substrates. In the eastern United States, pine bark often comprises as much as 75 to 100 percent (by volume) of container substrates. In the western U.S., barks of Douglas fir, redwood, and western red cedar are widely used. In addition, softwood bark is one of the most commonly used landscape mulches in the U.S.

However, there is a rising concern that the availability of bark for use in the nursery, greenhouse, and landscape industries will be limited in some markets due to alternative demands (e.g. industrial fuel), reduced timber production, and closing or relocation of primary timber processing mills to other regions or abroad (2, 4, 8). In the late 1970s, the horticultural industry began to realize the pressure of limited bark supplies as bark for fuel began to gain momentum in response to the energy crisis and other factors (8). In recent years, rising energy prices has led to decreased bark availability because of the roles of price in two directions: higher energy prices makes bark more attractive as an economical fuel (11); and, bark transported out of its generation location becomes more expensive. Furthermore, the relocation of primary timber processing mills to other regions or abroad further constricts bark supplies within some regions.

This study evaluates the quantitative relationship of timber harvest and the generation of bark as a timber residue based on the most up-to-date sources. Bark disposal is further analyzed, with emphasis on horticultural usage. Bark supply is assessed up to 2050 based on the projection of the future timber situation in the United States. Our focus is on the handling of the large quantity of bark as a by-product, residue or waste of the forest industry.

Bark utilization market. Bark is a by-product of the forest industry products sector, obtained when peeling trunks of trees. Bark can make up 6 to 22 percent of the bulk of the trunk (15). As the economic value of bark has been both quantitatively and qualitatively much less than that of wood, it was considered as a worthless waste product to the forest industry for many years. Often bark was given away for free or at a minimal price. As a main product, on a small scale, bark is harvested for a variety of special purposes such as tannins and dyes, spices and incense, medicine or phytotherapy, cork, construction material, etc. (15). Beneficial uses of bark relative to agriculture such as soil amendments and animal bedding have been known.

With the rapid economic development after World War II, bark developed into a profitable segment known as the 'horticulture bark industry' (4), and was used mostly for landscaping. In the meantime, bark was tested extensively in many

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agricultural labs and research stations as a component of container substrates with the development of container production in ornamental horticulture demanding large quantities of soilless 'media' or substrates (6, 9, 12).

In the process of bark gaining the status of the 'standard' component of container substrates, the forest industry itself looked for various methods for better utilization of bark and wood residues other than burning and dumping into landfills. Bark is primarily used as industrial fuel. Due to the energy crisis of the 1970s and environmental restrictions, research focused on bark and wood residues as energy resources (8, 11).

The Clean Air Act Amendments of 1970 and other environmental regulations and policies since then have shaped the methods by which the forest products industry has made its products and generated and consumed energy (1, 7). Ingram et al. (5) reported that during the late 1960s about 20 percent of Florida's sawmills and most of the pulpmills utilized pine bark for fuel but that by the 1990s almost all operations generating large quantities of pine bark utilized at least part of it for fuel. The result is that the forest products industry now generates about 50% of its own energy needs by making use of its wood residues and byproducts. The forest products industry consumes about 14% of domestic manufacturing energy use, making it the third largest industrial consumer of energy, behind only petroleum and chemicals (3). Besides its use in horticulture, bark has only minor usages in other areas, including fiber, building insulation, animal bedding, absorption and filtering, and chemical feedstocks (1, 15).

Factors affecting bark production. Bark production is affected by many factors, which range from the influence of the tree itself; to the structure of harvested timbers; to those factors such as harvest technology and methods, regional trade, and long-term macroeconomic activity. Accurate measurement of bark production is the basis for any further estimation of bark volume and quantity. For a single tree, the bark volume relative to wood is calculated by stem diameter and bark thickness. Those two factors are mainly decided by species, age, height in a stem, and silviculture management (1). Regression equations between bark thickness and diameter have been formed for many species. Because most bark contains numerous fissures and voids, bark volume percentages should be adjusted downward to allow for this factor. Unfortunately, void volumes have been calculated for relatively few species and thus estimation of this factor may be necessary (1). Silvicultural practices such as fertilizing, weeding, and thinning can affect the volume of bark relative to wood, although quantification of this effect largely remains to be done.

Debarking technology has a direct effect on how much bark is peeled from the log. Sawmills use either ring debarkers or Rosserhead debarkers, while most wood-panel and pulp and paper mills debark their roundwood in drum debarkers. Debarking is never totally effective and different end products have different tolerances to the amount of unremoved bark. For example, a requirement in most pulping processes is generally no bark, while larger quantities of bark can be incorporated deliberately into the central layer of a three-layered particleboard (17). The result is that primary wood processors can generate different volumes of bark from exactly the same feedstock if there are different debarking methods and end product structures. Besides the mainstream central debarking, logs are debarked at the harvest site in certain situations. In such cases, the bark is discarded back to the forest land and no bark byproduct is generated.

From the regional level, trade of wood products can shift the balance of bark generation. Some logs are traded with bark on and this results in different locations of wood harvest and bark generation. Other forest products, such as chips, debarked roundwood and sawmill slabs, are traded without debarking. The result is a mixture of self- or local-supplied feedstock and outside-supplied feedstock with or without bark for some primary wood processors.

Over time, the demand side of the forest products market guides the direction of products structure. The demand is largely based on dynamics of macroeconomic activity and population. In the long term, species structure, management intensity, rotation of plantation stand, harvest technology and methods can be gradually shifted or fluctuated. The consequence is that the generation of bark will be subtly affected.

Materials and Methods

Data collection and statistics. Statistical data of forest resources, timber product output and use, forest products market, and wood and wood waste as energy resources are reported and updated frequently by both state- and federal-level agencies. As for natural resources, the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) requires the Secretary of Agriculture to conduct an assessment of the nation's renewable resources every 10 years (4, 14). The national RPA timber assessment has been conducted five times with the latest report as a technical document supporting the 2000 USDA Forest Service RPA Assessment. This report analyzed historical timber removals, harvest, growth, and

Table 1. Area of timberland in the U.S. by region, 1952–97 with projections to 2050 (*million acres*)[z].

	Historical						Projections				
Region	**1952**	**1962**	**1977**	**1987**	**1997**	**2002**	**2010**	**2020**	**2030**	**2040**	**2050**
North	154.3	156.6	153.4	154.4	159.4	158.7	159.4	157.9	155.6	153.1	151.0
South	204.5	208.7	199.6	197.3	201.1	202.7	200.3	199.6	199.3	198.6	197.8
Rocky Mountains	66.6	66.9	60.2	61.1	71.0	70.6	71.4	71.3	71.2	71.0	70.9
Pacific Coast	83.4	82.9	79.1	73.5	72.2	71.5	71.0	70.3	69.9	69.6	69.3
Total[y]	508.9	515.1	492.4	486.3	503.8	503.5	502.1	499.2	496.0	492.2	489.0

[z]Data were compiled from Haynes (2003), Powell et al. (1993), Smith et al. (2001), Smith et al. (2003), and Waddell et al. (1987).

[y]Data may not add to totals because of rounding.

Table 2. Softwood and hardwood timber harvest in the U.S. by region, 1952–2001 with project to 2050 (*million cubic feet*)[z].

Region	Species	Historical					Projections				
		1952	1986	1991	1996	2001	2010	2020	2030	2040	2050
North	Softwood	596	901	907	816	787	817	786	790	806	818
	Hardwood	1381	3178	3233	2693	2559	3070	3341	3639	3869	4113
	All[y]	1977	4079	4140	3509	3346	3887	4127	4429	4675	4931
South	Softwood	3036	5302	5505	6155	6234	5703	6743	7722	8299	8954
	Hardwood	1933	2777	3108	3438	2863	4588	4700	4700	4684	4650
	All	4969	8079	8613	9593	9097	10291	11443	12422	12983	13604
Rocky Mountains	Softwood	497	853	845	594	565	781	825	864	902	912
	Hardwood	10	95	93	94	69	92	98	103	110	113
	All	507	948	938	688	634	873	923	967	1012	1025
Pacific Coast	Softwood	3393	4289	3924	2472	2434	2548	2667	2633	2811	2991
	Hardwood	37	197	274	170	172	525	491	460	436	425
	All	3430	4486	4198	2642	2606	3073	3158	3093	3247	3416
U.S.	Softwood	7522	11345	11181	10036	10020	9848	11021	12009	12818	13674
	Hardwood	3361	6248	6708	6395	5662	8346	8707	8985	9188	9393
	All	10883	17593	17889	16430	15683	18194	19728	20994	22006	23067

[z]Data were compiled from Haynes (2003), Powell et al. (1993), Smith et al. (2001), Smith et al. (2003), and Waddell et al. (1987).

[y]Data may not add to totals because of rounding.

inventory data in the United States as well as a bioeconomic modeling framework for the timber projections up to 2050 (4). This framework has evolved over more than two decades and by far provides the most reliable projection on future timber situation. However, this report has not included any projection component on wood waste production. Consequently, the future generation of bark can only be estimated based on historical correlations.

We collected historical data of bark generation as a base for the analysis of the correlation between bark production and timber harvest. Beginning from 1986, bark generation and its utilization were reported every five years at regional level for the following seven regions: Northeast, North Central, Southeast, South Central, Pacific Northwest, Pacific Southwest, and Rocky Mountain (10, 13, 14, 16) indicating that the value of bark can no longer be ignored. However, while timber products output and use are reported to the county level with detailed species groups through a 100-percent canvass of all primary wood processing mills in a state, bark and other residue (shavings, sawdust, coarse residue) are reported as a total number of the whole state. Thus, currently there is no data available to analyze the relation between bark generation and single tree species and only regional level relationships can be evaluated. The use of bark is currently reported as fiber, fuelwood, miscellaneous, and not used. Fiber is incorporated into such products as particleboard. Fuelwood is believed to be used as industrial fuel onsite, with other kinds of fuel negligible. Miscellaneous is an ambiguous word and this could include any use of bark other than fuel and fiber. While no further details are available for this grouping our assessment is that this grouping is mainly directed to various horticultural uses.

We included the bark data of 1986, 1991, 1996, and 2001 for the analysis. Linear relations between timber harvest and corresponding bark generation were developed at the regional level for softwood and hardwood, respectively. Simple lin-

Table 3. Bark generation by species type from 1986 to 2001 in seven subregions of the U.S. (*thousand dry tons*)[z].

Region	Bark type	1986	1991	1996	2001
Northeast	Softwood	212	1667	247	246
	Hardwood	402	2520	942	941
	Total[y]	614	4187	1189	1189
North Central	Softwood	394	336	466	417
	Hardwood	1919	2238	2329	2335
	Total	2313	2574	2795	2752
Southeast	Softwood	4174	4092	4567	2552
	Hardwood	1800	1687	2012	1324
	Total	5974	5779	6579	3876
South Central	Softwood	3864	6027	5452	5585
	Hardwood	2333	3715	3157	2991
	Total	6197	9742	8609	8576
Rocky Mountains	Softwood	1297	1393	1521	1402
	Hardwood	30	30	22	3
	Total	1327	1423	1544	1405
Pacific Northwest	Softwood	4217	3501	2624	2620
	Hardwood	99	100	198	199
	Total	4316	3601	2822	2819
Pacific Southwest	Softwood	1418	1395	991	991
	Hardwood	0	13	1	1
	Total	1418	1408	992	992
U.S.	Softwood	15576	18411	15868	13813
	Hardwood	6583	10303	8661	7794
	Total	22159	28714	24530	21609

[z]Data were compiled from Powell et al. (1993), Smith et al. (2001), Smith et al. (2003), and Waddell et al. (1987).

[y]Data may not add to totals because of rounding.

Table 4. Fitted linear model[z] between bark generation and timber harvest in seven subregions of the U.S.[y]

Region	Type	Parameter (slope)	R^2	Two-sided P-value
Northeast	hardwood	0.89	0.732	0.0646
	softwood	1.01	0.516	0.1719
North Central	hardwood	1.42	0.976	0.0016
	softwood	1.62	0.987	0.0006
Southeast	hardwood	1.38	0.992	0.0003
	softwood	1.44	0.956	0.0040
South Central	hardwood	1.69	0.984	0.0008
	softwood	1.67	0.983	0.0009
Rocky Mountains	hardwood	0.25	0.875	0.0194
	softwood	1.88	0.948	0.0051
Pacific Northwest	hardwood	0.99	0.782	0.0465
	softwood	1.29	0.994	0.0002
Pacific Southwest	hardwood	0.07	0.494	0.1853
	softwood	1.52	0.996	0.0001

[z]Analysis by linear regression through the origin (intercept set to be zero).

[y]Linear models were developed based on bark generation and timber harvest data compiled from Powell et al. (1993), Smith et al. (2001), Smith et al. (2003), and Waddell et al. (1987); (see also Table 2 and Table 3 of this paper).

ear models were developed with the timber harvest as an independent variable, and bark generation as the dependent variable:

$$Y_i = \beta_1 X_i + \varepsilon_i$$

where: Y_i is the historical, regional bark generation, in unit of thousand dry tons; β_1 is a parameter (the slope); X_i is the historical, regional timber production, in unit of million cubic feet; ε_i is a random error term with independent $N(0, s^2)$.

The intercept of the simple linear regression model has no meaning as bark is a timber byproduct; therefore the correlation was regressed through the origin (with no β_1 term). The analysis was conducted using SAS (SAS 9.1, 2003, Cary, NC). The developed models were used to calculate future bark generation for different regions by using the projected timber harvest (4) for the independent variable X_i.

Results and Discussion

Analysis of historical forest products data indicated that between 1952 and 2002, total area of U.S. timberland decreased 1 percent, from 509 to 504 million acres (10, 13, 14, 16; Table 1). Over the next 50 years, a projected U.S. population increase of 126 million will result in a projected net loss of U.S. timberland area of about 15 million acres, or a loss of about 3 percent between 1997 and 2050 (4; Table 1). Between 1991 and 2001, U.S. timber harvest declined 2206 million cubic feet (mcf), or 12 percent, from 17,889 to 15,683 mcf (Table 2). Only the Southern Region experienced an increase in timber harvest during this period (6 percent). It is projected that total timber harvest will increase from 17,889 mcf in 1991 to 23,067 mcf by 2050, or a 29 percent increase.

Overall, the timber harvest has been relatively stable or slightly decreased since 1986 and this trend will continue for several years through the first decade of the 21st century (4, 13, 14; Table 2). It is worth noting that the projected softwood harvest of 2020 (11,021 mcf) is still below the level of 1986 (11,345 mcf). Softwood bark generation in the Southeast was steady from 1986 through 1996 (Table 3), but dropped about 40% by 2001. Transportation cost is a major limitation in bark distribution and can have a significant impact on bark availability out of a local area. Similar trends occurred in the Pacific Northwest and Southwest.

Overall, the bark utilization rate increased from about 95% for 1986 to more than 97% for 1996 and 2001 (Fig. 1). For

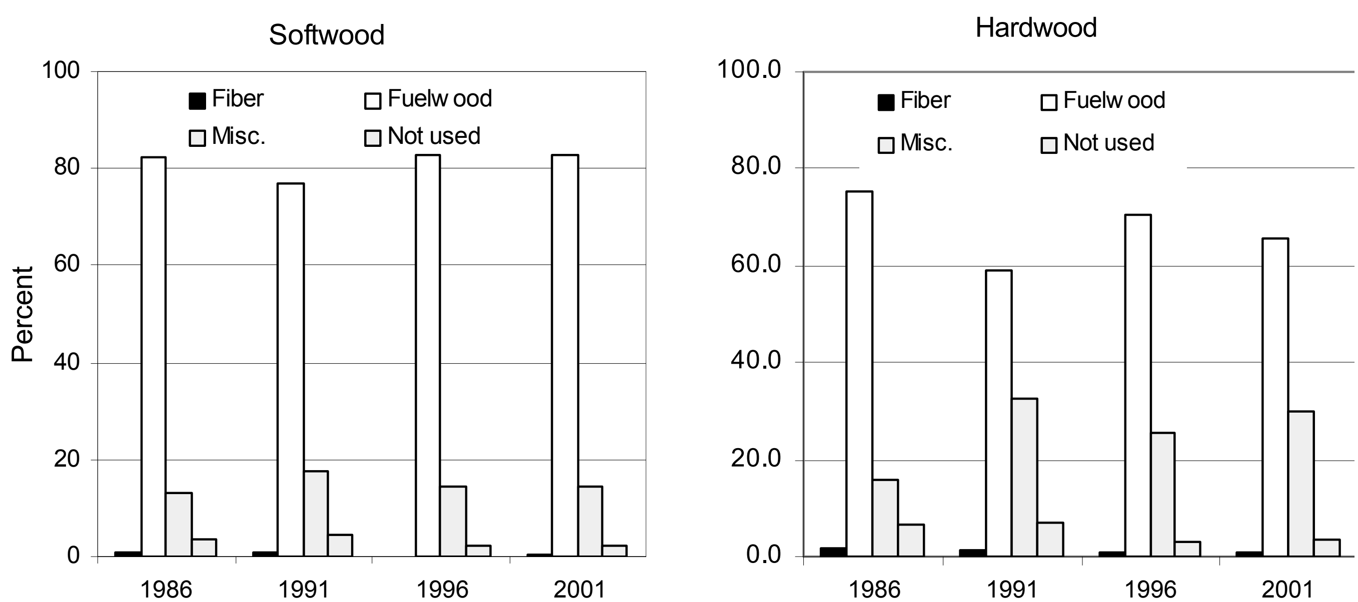

Fig. 1. Historical usage of bark from 1986 to 2001 in the U.S. Data compiled from different sources (Powell et al., 1993, Smith et al., 2001, Smith et al., 2003, Waddell et al., 1987) were used to construct this figure.

Table 5. Projection of bark generation by region and species type from 2010 to 2050 (thousand dry tons)[z].

Region	Species	2010	2020	2030	2040	2050
North	Softwood	515	495	498	508	515
	Hardwood	3408	3709	4039	4295	4565
	Total[y]	3922	4204	4537	4802	5081
South	Softwood	8954	10587	12124	13029	14058
	Hardwood	7295	7473	7473	7448	7394
	Total	16249	18060	19597	20477	21451
Rocky Mountains	Softwood	1468	1551	1624	1696	1715
	Hardwood	23	25	26	28	28
	Total	1491	1576	1650	1723	1743
Pacific Coast	Softwood	3363	3520	3476	3711	3948
	Hardwood	520	486	455	432	421
	Total	3883	4007	3931	4142	4369
U.S.	Softwood	14300	16153	17721	18943	20236
	Hardwood	11245	11692	11993	12201	12408
	Total	25545	27845	29715	31145	32644

[z]Projection based on combination of parameters developed from linear regression models presented in Table 4 and projection data by Haynes (2003).
[y]Data may not add to totals because of rounding.

both softwood and hardwood bark, the largest share was fuelwood. Except a slight dip in 1991, about 82 to 83 percent of total softwood bark was used as fuelwood. The next group was miscellaneous, a category that stabilized at about 15% in recent years. Hardwood had a relatively lower fuelwood usage and higher rate of miscellaneous. Bark used as fiber has remained at a very low level (Fig. 1). The Southeast and South Central subregions continue to produce the largest amount of bark, followed by Pacific Northwest (Table 3). It has to be noted that these bark data were obtained through canvass of primary wood-using mills according to USDA Forest Service Forest Inventory and Analysis. Therefore, the accuracy of these data is limited by the canvass responses, which themselves are often estimated by mills.

Linear regression models were fitted for softwood and hardwood harvest and bark generation for seven subregions (Table 4). Only Northeast softwood bark and Pacific Southwest hardwood bark had no significant linear relation with their timber harvest; there is a weak linear relation for Northeast hardwood bark and timber harvest ($R^2 = 0.732$, $P = 0.065$). Examination of the data indicates that the Northeast had abnormally higher hardwood and softwood bark weights in 1991 compared with the consequent timber harvests. While the Northeast had similar softwood timber harvests for each year (678, 651, 545, and 545 mcf for 1986, 1991, 1996, and 2001 respectively), the corresponding softwood bark weight was 212, 1667, 247, and 246 thousand dry tons. The same is true with the hardwood bark. However, the accuracy of these high numbers of bark in 1991 for the Northeast subregion is difficult to verify. The reported low hardwood bark quantities in the Pacific Southwest (Table 3) is largely because fuelwood was the only major type of roundwood harvested in this area (there is no bark generated as byproduct for fuelwood production). Different slopes of Table 4 also indicate regional and subregional differences in bark generation due to various factors as described earlier.

With the above variance and contributing factors in consideration, we fitted parameters to predict future bark generation based on the timber harvest provided by Haynes (4) for four regions (North, South, Pacific Coast, and Rocky Mountains) from 2010 to 2050. It is projected that the total bark output of 2050 will be 32,644 thousand dry tons, with softwood bark at 20,236 thousand dry tons and hardwood bark at 12,408 thousand dry tons (Table 5). Compared with 1996, total bark residue will increase 33 percent (0.5 percent annually). Softwood and hardwood bark residue will increase 28 and 43 percent, respectively (0.5 and 0.7 percent increase annually, respectively). Softwood bark harvest will be above the level of 1996 (Table 2) until about 2020.

Several important implications can be made from this analysis and projection of bark generation. First, most bark is used by the timber industry as fuelwood. Secondly, with the predicted slow increase in timber harvest, overall bark generation will have a modest increase over the next fifty years. Thirdly, major variations exist among regions and subregions for the bark generation rate as reflected in Table 4 and Table 5. While the overall market will reflect the national bark generation trend, the availability of bark for the horticulture industry is expected to be greatly affected by local wood industry production structures and development. Costs of available bark is expected to increase in response to increasing freight costs and increased demand. Finally, as an overall trend, there will be less availability and affordability of bark for the horticulture industry with current and predicted economic conditions.

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