FS-4000-1 (8/76)

USDA-Forest Service	1. Number	2. Station
	SRS-4702	Southern Research Station
RESEARCH WORK UNIT DESCRIPTION	3. Unit Location	
Ref: FSM 4070	Blacksburg, Virginia	

4. Research Work Unit Title

Integrated Life Cycle of Wood: Tree Quality, Processing, and Recycling

5. Project Leader (Name and address)
Philip A. Araman, Southern Research Station, Brooks Forest Products Center, Virginia Tech University, Blacksburg, Virginia 24061-0503

6. Area of Research Applicability	7. Estimated Duration
National	5 Years

8. Mission

To enhance wood resource conservation and sustainability through advanced timber analysis and wood processing, and effective wood product recovery, reuse, and recycling.

9. Justification and Problem Selection

Demands for wood products by the American public are at all time highs. Population increases will only intensify the demand for wood products as noted in Forest Service RPA documents. At the same time, we strive for sustainable forests, continue to reduce timber availability from federal forests, and attempt to meet American wood product needs. Given these conditions, it is imperative for us to improve our understanding of the wood resource base, increase the yield and quality of products from felled trees, and lessen demands for new timber by recovering, reusing and recycling wood products into high-value products.

Major yield and value improvements can be made when converting tree length roundwood to veneer logs, sawlogs, peeler logs, LVL logs, OSB logs, and pulpwood. Tremendous waste results from poor processing and decision-making. Training tools and automated systems are needed to make major processing improvements and proper product allocation. Furthermore, Forest Inventory and Analysis (FIA), Forest Health Monitoring, and forest management research work units need advanced and reliable

Signature	Title	Date
Recommended:	Assistant Director for Research	
	Assistant to Staff Director	
	Staff Director	
Approved	Station Director	
Concurred	Deputy Chief for Research	

technologies to evaluate tree stems for volume, quality, and products. Research that ties tree length bucking and allocation decisions to advanced data recording and analysis systems is needed. Such a system could use digital cameras to provide tree stem images for handheld or office computers that assess tree volume and grade, and make product allocation decisions. Forest Health Monitoring could also be aided by digital camera crown measurements and reliable sensor equipment to detect decay in standing timber.

Meshing of human needs with biological capacity is central to the success of sustainable forestry. It is apparent that wood products from the forest will continue to be an important human need well into the foreseeable future. As forest lands are being managed to include a flow of wood products (among other benefits), it is critical to know: (1) the quantity of wood in each tree stem; (2) the quality of wood in each stem; and (3) how quantity and quality depend on land management activities. Current, field-based forest inventory timber assessment methods are time-consuming and need to be modernized. We expect that the use of digital imagery--collected in the field--combined with computer-based analysis--either in the field or in the office--can greatly increase efficiency and accuracy of timber volume estimates. Furthermore, by combining automated analysis of those digital images with product allocation software, more accurate tree value assessments can be obtained. Ground-based digital imagery can also be effective for monitoring canopy closure and foliage color and retention for forest health issues. Tree quality estimation can also be improved through nondestructive sensing of decay in tree stems. A simple, fast, and reliable sensing mechanism that provides an estimate of lower tree stem soundness would be useful for inventory, monitoring, and research. Finally, evaluation of tree volume and value needs to be tied to historical, silvicultural treatments so that the impact of management activities on wood products can be determined and applied to future management decisions. For wood products to be part of sustainable forest management, **reliable and accurate nondestructive timber assessment and allocation methods are needed to evaluate standing and felled trees**. (Problem 1)

As solutions to Problem 1 are produced, they will improve land managers' ability to reliably value standing trees and wood processors' ability to properly buck and processes tree-length roundwood. Results will also aid forest inventory personnel to accurately determine the volume and value of timber. Improved capabilities to monitor forest canopy and tree stem soundness will provide forest health specialists with better information regarding tree health and vigor. Silvicultural researchers will also benefit from solutions to Problem 1, as tools and techniques developed will enable them to better understand wood product implications of managerial treatments. Silvicultural research results will then feed back to management prescriptions that include wood product sustainability. Approximately 0.75 scientist, along with cooperators, for 5 years will address this problem at a cost of $150K/year. The likelihood of successful completion of the solutions to this Problem are about 75%. Due to limited appropriations for this RWU, outside funding will be pursued to fully support this research.

The U.S. primary hardwood processing industry, which produces over 11-12 billion board feet of sawn products per year, faces many interrelated market, product, processing, and resource problems. Expanding international markets further exacerbate many of these problems. Wood processors need to improve yields and product quality to meet product demands with less timber. One option is to

modernize with vision system-controlled, computer-aided, and computer-controlled processing. Wood processors must also deal with an array of resource problems resulting from high demand for a few species and an abundance of low-grade material in forests and at mills. Solutions to these problems would allow forest products manufacturers to better utilize hardwood resources, both in the forests and at mills. Effective solutions will have positive effects on resource sustainability and on employment opportunities in forested rural areas. While the important wood resource in the Southern Appalachians is predominantly hardwoods, solutions to these problems could also be applied to the softwood timber industry to reduce processing waste and decrease timber needs.

Research is needed to help the forest products industry improve timber processing. Technology development efforts would utilize vision systems and computer controls in automated processes. The U.S. is the No. 1 producer of sawn hardwoods in the world, and has the resources to continue to supply products sustainably through improved processing. For the U.S. hardwood industry and, the overtaxed softwood industry to be sustainable suppliers of wood products, **wood processing technology and equipment must be improved to efficiently evaluate and process wood resources**. (Problem 2)

Solutions to Problem 2 are important to hardwood and softwood sustainability and to employment in rural areas dominated by hardwood forests. Lack of automation in the primary processing area causes waste and low product yields, and increases demand for additional timber harvesting. This trend must be reversed to keep U.S. hardwood forests sustainable (economically and biologically). For example, computer-aided sawmill edging and trimming could increase overall product and grade yield by 5-20%. If fully implemented, this could translate into 0.6-2.4 billion board feet per year of decreased timber needs. Machine vision systems combined with computerized grading of hardwood lumber has several advantages: (1) it would help insure the accuracy of grading; (2) it would reduce the number of times boards need to be graded and restacked from 3-8 times to 1; (3) it would make lumber more acceptable to purchasers; and (4) it would provide a means to increase the grade of some low-grade lumber. Around $1,000,000 could be saved annually in grading costs and even greater amounts could be realized through increased lumber value (upgrading lumber). Automated grading of pallet parts research will also continue. Graded parts placed in proper locations can extend the useful life of pallets and thereby reduce the need to produce new pallets from timber. Successful completion of internal log scanning work will encourage the use of computer-aided processing of logs into veneer and sawn products. In addition, log scanning would make possible the efficient processing of parts directly from logs. The likelihood of successful completion of solutions to this Problem are about 60%. Approximately 1.5 scientists, along with cooperators, for 5 years will address this Problem at a cost of $300K/year. Due to limited appropriations for this RWU, outside funding will be pursued to fully support this research.

In addition to improved processing, timber demands can be reduced by other major activities that extend the life of wood. Wooden pallets readily lend themselves to repair and recycling; these opportunities need to be continued and expanded. These efforts would reduce both hardwood and softwood timber needs. Presently, around 40% of sawn hardwoods and large volumes of softwoods are used in pallets. After initial use, they could be recovered, repaired, and reused, and at some point, recycled into other useful products to reduce timber harvesting needs. In addition, other solid

wood products, such as softwood house deck materials, could also be recovered and reused as decking or other solid wood products.

Research is needed to help the pallet and house decking industries extend the life of the products that they produce and to reduce the volumes of materials presently ending up in landfills. Therefore, **to extend the life of our resources, we need to effectively refurbish and reuse wood pallets and other solid wood products or convert them to alternative high value products**. (Problem 3)

Solutions to Problem 3 are very important to hardwood and softwood sustainability and to employment in urban areas which lack trees, but containing people needing jobs and companies needing products. Companies also face major disposal problems in urban areas with products such as used pallets and decking. These also create major problems at overflowing landfills. The development of tested repairs and tested performance of a new Certified Pallet Repair (CPR) pallet will help maintain and increase pallet repair and reuse. The development of “green” products from used pallets and decking will benefit many and extend the life of wood. Implementation of the solutions to this problem will continue to shrink the need for new wood. Approximately 0.75 scientists, along with cooperators, for 5 years will address this problem at a cost of $150K/year. The likelihood of successful completion of the solutions to this Problem are about 80%. Due to limited appropriations for this RWU, outside funding will be pursued to fully support this research.

In summary, our research and development efforts are aimed at assuring timber sustainability by helping hardwood and softwood processors maintain or improve yield, reduce waste, and use less timber. Specific efforts include developing advanced processing systems and training tools, increasing use of low-grade hardwood sawtimber and nonselect species, and helping the pallet industry develop effective repairs and viable recycling options. Viable recycling options for other discarded solid wood such as decking materials will also be pursued. Support for this research problems is well documented in the April 1996 report, "Research Priorities for North American Hardwoods 1996," by the National Hardwood Lumber Association. Our research addresses 3 of the first 5 most important needs and 8 of the first 13 needs, as seen by industry respondents. Much of our research will be conducted in cooperation with members of the Hardwood Utilization Consortium (HUC). Members include the USFS Northeastern and Southern Stations; USFS Northeastern Area and Region 8 S&PF; Virginia Tech; West Virginia University; Robert C Byrd Hardwood Technology Center; and the National Hardwood Lumber Association. Several others are also being considered for membership. We will also attempt to obtain additional funding through the consortium.

Our tree stem and tree health evaluation research will support FIA and Forest Health Monitoring by providing advanced data collection and analysis techniques. This will enhance their efforts to reduce inventory cycles and improve the quality of their data. The need for advanced data collection is well documented in the April 1996 report, "Research Priorities for North American Hardwoods 1996," by the National Hardwood Lumber Association. Many others, including most State Foresters, are also strongly behind new or improved monitoring techniques and annual surveys.

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10. APPROACH TO PROBLEM SOLUTION

Problem 1: **Reliable and accurate nondestructive timber assessment and allocation methods are needed to evaluate standing and felled trees**.

This research will investigate the use and application of ground-based digital imagery, combined with image processing software and product allocation software to estimate tree volume, product allocation, and tree grade for inventory purposes. Use of digital imagery will also be evaluated for application to canopy and understory monitoring for forest health. Log bucking and product allocation software will be developed to provide total tree value estimates. Nondestructive, decay detectors will be evaluated for their ability to accurately estimate lower-stem soundness. Tools developed in these studies will be effective at assessing wood product impacts stemming from management activities. This problem area ties in very closely with the Unit's involvement in Station cross-cutting themes: "Inventory and Monitoring" and "Southern Appalachian Ecosystem Research and Sustainability".

Accomplishments planned for the next 5 years:

1. Evaluate the use of a nonmetric digital camera for forest inventory tree volume estimation.
2. Develop log bucking and product allocation software to provide optimal value and product estimates for each tree.
3. Integrate multiple, digital camera views with product allocation software to provide in-field tree quality and value estimates.
4. Evaluate the application of an ultrasonic decay detector to estimate soundness (health) of lower tree stems.
5. Evaluate the use of a digital camera for canopy closure, foliage assessment, and understory development for forest health monitoring.
6. Apply the technologies, developed above, to assessing tree value and wood products resulting from various silvicultural treatments on various sites.
7. Evaluate and modify an ultrasonic decay detector for use in monitoring and assessment of in-service utility poles.

We rely heavily upon cooperative research studies with universities and others to complete needed research. Our cooperators provide skills and expertise to expand our abilities. Technician support will be provided from within the work unit, by Virginia Tech or by temporary hires. We are, or hope to, team with the following on the above planned accomplishments: FIA units(1-4); Forest Health units(4-5); SRS-4101(1-4,6); NE-4701(2,6); NE-4353(1-4,6); Virginia Tech(1,3,5,6); Michigan Tech(2-3); and Private Consultant/pole and electronic industry(7).

Environmental consideration: The studies in this Problem Area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, " Categorical Exclusion from Documentation in an EIS or EA.". Where environmental concerns exist, regarding particular studies, these will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs.

Problem 2: **Wood processing technology and equipment must be improved to efficiently evaluate and process wood resources**.

In this research we will develop and use expert systems and vision systems to support computer-aided and automated hardwood sawmill edging and trimming; develop a scanner/computer system to identify defects on rough lumber; support the development of a prototype vision system to automatically grade and upgrade rough lumber; help determine, with computer simulation, the optimal sawing patterns to produce hardwood lumber; investigate links between log scan data and sawmill sawing decisions and veneer log processing decisions; develop products or better processes to improve the use of low-grade and nonselect hardwoods; and develop and evaluate automated production systems to grade pallet parts. Much of these efforts are team efforts with our cooperators. The Unit has had a good record with some technology having already been commercialized. Some major awards have been won. This problem area ties in very closely with the Unit's involvement in the Station's "Southern Appalachian Ecosystem Research and Sustainability" cross-cutting theme.

Accomplishments planned for the next 5 years:

1. Determine the scanning needs for an automated hardwood sawmill edging and trimming system.
2. Develop an algorithm for optimal edging and trimming in real time.
3. Design and demonstrate a computer-aided sawmill edging and trimming system.
4. Determine and develop a complete prototype vision system to identify defects and board outlines to automatically grade and upgrade rough lumber.
5. Develop a color-sorting system for upgrading the use and value of lumber.
6. Develop a link between log scan data and a sawmill simulator to produce lumber.
7. Evaluate hardwood sawmill lumber production to maximize value through a sawmill simulator.
8. Develop the link between log scan data and veneer log decisions.
9. Develop an ultrasound scanning system to scan pallet parts.
10. Develop a pallet part grading system based on ultrasound scanning and visual grading rules.
11. Examine the feasibility of identifying wood species automatically using ultrasound scanning.
12. Complete the vision system for identifying and labeling internal log defects using computed tomography (CT) imagery.
13. Develop a log breakdown procedure based on knowledge of internal log defects.
14. Develop new primary production concepts to maximize product value.
15. Improve yields in the production of rotary cut hardwood veneer and furniture plywood.
16. Develop and evaluate viable (technically and economically) industrial CT scanning for hardwood logs.
17. Develop and evaluate the use of ultrasonic scanning to detect wetwood infection in green lumber.

We rely heavily upon cooperative research studies with universities and others to complete needed research. Our cooperators provide skills and expertise to expand our abilities. Technician support will be provided from within the work unit, by Virginia Tech or by temporary hires. We are, or hope to, team with the following on the above planned accomplishments: NE-4701(4); FPL-4719(9); Virginia Tech(2,3,4,5,8,9,10,12); Michigan Tech(); University of Missouri(6,7,11,13); West Virginia University(1); NC State University(15); and private companies through SBIR's(3-6,9,14,16-17).

Environmental consideration: The studies in this Problem Area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, " Categorical Exclusion from Documentation in an EIS or EA.". Where environmental concerns exist, regarding particular studies, these will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs.

Problem 3: **To extend the life of our resources, we need to effectively refurbish and reuse wood pallets and other solid wood products or convert them to alternative high value products.**

This research will investigate and evaluate current and new repairs for damaged and used wood pallets and compare these to new pallets. The conversion of used pallet parts to solid wood products will be evaluated. This would include flooring, wainscot and furniture. Business plans for recovery operations will be developed. Pallet recycling assessments and landfilling of pallets and other solid wood will be determined. Other solid wood recycling such as reuse of decking will be investigated as well as making new solid wood products. This problem area ties in very closely with the Unit's involvement in the Station's "Southern Appalachian Ecosystem Research and Sustainability" cross-cutting theme.

Accomplishments planned for the next 5 years:

1. Determine the number of pallets recovered, repaired and recycled by the pallet industry.
2. Determine the severity of pallet landfilling and pallet recovery.
3. Determine the performance of the CPR repaired pallet.
4. Determine the usefulness of splicing short stringers to make full length stringers.
5. Determine the usefulness of glue that can be used on wet wood to be used to glue deckboards to stringers.
6. Determine the performance of new repair techniques.
7. Develop business plans for recovery operations.
8. Develop solid wood products from used pallet parts.
9. Develop solid wood products from used home decking material.
10. Determine the amounts of all solid wood entering landfills.
11. Adopt ultrasound scanning/grading system to sort recovered pallet parts.
12. Develop and test a species sorting system for recovered pallet parts.

We rely heavily upon cooperative research studies with universities and others to complete needed research. Our cooperators provide skills and expertise to expand our abilities. Technician support will be provided from within the work unit, by Virginia Tech or by temporary hires. We are, or hope to, team with the following on the above planned accomplishments: NE-4803(7,8,9); FPL-4719(11); Virginia Tech(1-12); EPA(1,2,3,10); U. Missouri(12); and private companies through SBIR's(8,9).

Environmental consideration: The studies in this Problem Area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, " Categorical Exclusion from Documentation in an EIS or EA.". Where environmental concerns exist, regarding particular studies, these will be evaluated within

individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs.

STAFFING:
This research will require three scientists per year, at an average RWU cost of $600 thousand. Current FY97 funding is $400 thousand. Current staffing includes two permanent scientists (including the Project Leader). Unit scientists will pursue outside funding to make up the difference between the annual appropriation and the $600 thousand needed to conduct this research. Increased federal funding would allow the work to be accelerated and expanded. A third permanent scientist would be added to the unit if appropriated funds increased. If the federal appropriation is not increased and we can't get the additional $200,000 from outside sources to fully fund this research program, research in Problems 1 and 3 would be delayed or decreased. Post-docs and cooperators would be used to accomplish the work where possible. Distribution of SY's is as follows:

Problem Number	Scientist-years (SY) per annum
1	.75
2	1.50
3	.75
Total	3.00

We rely on cooperative research studies with universities and others to complete needed research. Our cooperators provide skills and expertise to expand our abilities. Technician support will be provided from within the work unit, by Virginia Tech or by temporary hires. Close cooperation will be maintained with RVUR (WO), S&PF, NFS, VMPR (WO), SPPII (WO), FIA units, SRS-4101, NE-4701, NE-4803, SRS-4701, SRS-4851, NC-4701, SRS-4703, FPL-4719, EPA, industry associations, forest products industry, State forestry organizations, and universities in Virginia, North Carolina, South Carolina, Georgia, Mississippi, Missouri, and other states with hardwood resources. Being a major part of the Hardwood Utilization Consortium(HUC) with many of the groups mentioned above greatly enhances our abilities to complete our assigned research. The SRS-4702 PL is a co-coordinator for the HUC. The Challenge Cost-Share Program will be utilized with industry to increase funding for our research and development efforts. Cooperation with industry will continue to test prototype equipment, computer applications and new products. SBIR's will be used by some of our cooperators.