FINAL REPORT:

THE EFFECTS OF TIMBER HARVESTING ON PENNSYLVANIA FOREST SUSTAINABILITY

(Cooperative Agreement Number 95-2)

Submitted to

THE CENTER FOR RURAL PENNSYLVANIA

Submitted by

James C. Finley
Assistant Professor
Forest Resources
School of Forest Resources
The Pennsylvania State University
7 Ferguson Building
University Park, PA 16802

and

Stephen B. Jones
Extension Director
Alabama Cooperative Extension System
109D Duncan Hall
Auburn University, AL 36849-5612

Table of Contents

"The Effects of Timber Harvesting on Pennsylvania Forest Sustainability"

Executive Summary

Pennsylvania's forests are critically important to the state's economy and our quality of life. Covering nearly 60 percent of the Commonwealth, forests protect 25,000 miles of waterways, provide recreation, furnish clean air and scenic beauty, and offer us peace of mind. In addition to sustaining a forest-based, recreation and tourism industry, forests also furnish raw materials to a dynamic wood products industry. This manufacturing base including firms ranging from pulp and paper plants to Amish specialty shops, employs 100,000 workers and generates annual sales in excess of $4.5 billion. The economic and cultural vitality of rural Pennsylvania is dependent on the long-term sustainability of Pennsylvania's forests and the diverse industries they support.

The importance of the state's forests was documented with the passage of the Pennsylvania Hardwoods Development Council Act in 1988. One of the first actions of the Council was commissioning a comprehensive Needs Assessment (Stanturf 1989). Stanturf observed that the long-term success of the economic Council's development goal ". . . rests upon the sustainable supply of quality hardwoods." Stanturf believed that we must understand and anticipate resource sustainability issues so that programs can be forged to protect the productivity capacity of Pennsylvania's forestlands. To this end he offered a specific recommendation to "Survey a sample of recently harvested sites on private ownerships to rate the quality of silviculture being employed. . ." Documenting the condition of this forest is essential for understanding the changing nature of the resource, identifying research opportunities, monitoring management processes, and for fostering industry, agency, and education programs to ensure long-term resource sustainability.

Harvesting is the tool of silviculture. Properly designed harvests can provide economic returns as well as maximize other landowner objectives. Poorly designed harvests may lead to reduction in the quantity and quality of important hardwood species. Leading to future stands with limited management options.

Project Scope

This project, a timber harvesting assessment, considered that high-grade sawlogs are important and will remain essential to sustain the state's forest industry. Ensuring that these forests provide resources for today and tomorrow is important to the public, forest

landowners, and forest industry. The focus of the Timber Harvest Assessment Project (THAP) was on timber.

The American Forest and Paper Association (AF&PA), a national trade group that represents over 400 forest and paper companies, through the Sustainable Forestry Initiative (SFI), offers a definition of sustainable forestry. Sustainable forestry means managing our forest resources to meet the needs of the present without compromising the ability of future generations to meet their own needs by practicing a land stewardship ethic which integrates the growing, nurturing, and harvesting of trees for useful products with the conservation of soil, air, and water quality, and wildlife and fish habitats" (AF&PA 1995).

Forest Sustainability as offered by the AF&PA encompasses all benefits attained through forest management. THAP narrowed the focus to timber rather than assessing the broad scope of forest sustainability. In essence, sustaining timber resources through active management will protect and sustain many of the other values addressed in the AF&PA definition.

Project Goals and Objectives

The project had two main goals: Determine whether and to what extent current timber harvesting practices are affecting Pennsylvania's timber resource sustainability; and, recommend policy alternatives and actions for addressing the situation.

Assessing the effects of current harvesting on timber resource sustainability includes five objectives:

1) Create a Timber Harvesting Assessment Advisory Team.
2) Develop detailed assessment protocol.
3) Collect data sufficient to draw conclusions regionally and by ownership.
4) Analyze the results, establish baseline conditions, and project consequences of current practices
5) Identify future resource conditions.

Developing policy alternatives encompassed four objectives:

1) Compare projected future conditions to desired conditions.
2) Determine whether modifications to current practices are necessary to reach desired conditions.
3) Develop alternative policy and actions initiatives for achieving the desired conditions.

4) Recommend preferred alternatives.

Procedures

The first project goal was to determine whether and to what extent current timber harvesting practices are affecting Pennsylvania's timber resource sustainability. To develop measurement protocol and a metric for conducting the research, a group of natural resource professionals, the Timber Harvesting Assessment Advisory Team (THAAT, Appendix A) was assembled. THAAT aggressively sought and secured additional funding and support (Appendix B), expanding on CRP base funds. THAAT members represented a wide range of professional employment, experience, and education, including forest industry, private forestry consulting, US Forest Service, Pennsylvania Bureau of Forestry, Pennsylvania Game Commission, and Penn State University. THAAT also solicited and received advice and input from Drs. Ralph Nyland and Mary Ann Fajvan, faculty members at the State University of New York, College of Environmental Sciences and Forestry, and West Virginia University, respectively.

Timber harvests selected for evaluation were harvested between April 1, 1992, and March 30, 1994. Individual assessment sites were located using USGS topographic sheets. Topographic sheets with more than 50 percent of their coverage outside the state and those with more than 60 percent urban were excluded from the sample. Ultimately 100 topographic sheets distributed according to harvesting intensity were randomly selected and Bureau of Forestry service foresters identified potential assessment sites using selection protocol.

During the 1995 field season 97 sites received evaluations. Seventy-three sites were on private ownerships (i.e., 72 on non-industrial private forests (NIPFs) and 1 on forest industry). Public ownerships accounted for 24 assessment sites (i.e., 2 Allegheny National Forest, 11 Pennsylvania Game Commission, and 11 Pennsylvania Bureau of Forestry). Each of the NIPF owners received a mail survey to determine their objectives, the role of a forester in the harvest, and other information relative to the harvesting decision and its outcome. Nearly 60 percent of the NIPF owners responded to the survey; however, this data has not been analyzed.

The metric established to assess timber sustainability depends heavily on existing research and inventory based protocol. The information collected focused on the existing condition of the site, overstory and understory vegetation, as well as providing data for constructing pre-harvest conditions. Determining pre-harvest conditions was essential

since it provided the benchmark against which treatments were compared. Ultimately the findings reported here depended on:

- Species — the proportion of high, medium, low, and non-commercial species.
- Quality — suitability of residual trees for developing sawlog potential.
- Diameter Distribution — all residual trees greater than 1 inch diameter breast height (DBH) were tallied. All stumps were also measured and DBH calculated for all harvested trees.
- Regeneration — focuses on stocking levels for species classes (i.e., high, medium, and low value).
- Site Disturbance — the amount of the site disturbed, the use of erosion and sedimentation control practices, and depth of rutting.
- Tree Damage — square inches of stem damage on the first log and the proportion of the crown damaged on residual trees served as an index.

Data Analysis

A key element in the data analysis process is contained in the AF&PA definition of forest sustainability —". . . without compromising the ability of future generations to meet their own needs." THAAT members addressed this issue, for timber, by comparing the future options available for landowners or managers in the post-harvest stand with the options available in the reconstructed pre-harvest stand. Data on species, tree quality, diameter distribution, regeneration, site disturbance, and tree damage were assessed to determine whether the harvesting practice on the site had narrowed the range of options — the potential of that stand — for the future. We found that options available were driven by the native productivity of the site and by the trees on that site.

Many stands examined in the assessment had been entered at least once before the assessment. These cutting activities did modify the stands in which they occurred, but we used the condition prior to the harvest we were assessing as the benchmark for available options. Given this range of options, we strove to reach consensus on whether the range of options post-harvest was as wide or wider than the range of options available pre-harvest — a clearly sustainable situation — or whether it had been prohibitively narrowed — a clearly unsustainable situation. We found that the stands we assessed represented a continuum from sustainable through possibly sustainable to unsustainable.

We also understood that the range of options is defined not only by the practices but by the stands themselves. In a stand with limited high quality hardwoods in the pre-harvest stand, a relatively light removal with some attention to residual stand damage

may remove all seed sources of valuable species and result in an assessment of partially sustainable practice but unsustainable outcome. In a stand with resilient soils and abundant high quality hardwoods, the same practice might be assessed as sustainable, largely because of the resilience of the forest itself.

Results

The THAAT used data summaries for each stand and open discussion to assess the sustainability of individual harvests. Results are presented for stands that received at least fifty percent agreement within the THAAT — ninety percent of the 97 tracts. As described above, the team assessed the practice and the outcome for each harvest.

From a practice perspective, THAAT assessed twenty-five percent of the 87 harvests as sustainable, thirty percent as possibly sustainable, and forty percent as unsustainable. The primary differences between practices that received sustainable assessments and those that were assessed as unsustainable showed that sustainable practices tended to:

- maintain or improve tree species composition,
- suggest that silvicultural principals rather than tree diameters alone were used to select trees for harvest,
- retain greater proportions of Acceptable Growing Stock (AGS) in the residual stand,
- show more cutting or tending in all diameter classes,
- establish, and, where necessary, release regeneration,
- install soil erosion and sedimentation control practices, and
- protect residual trees from stem and crown damage.

From an outcome perspective, THAAT assessed thirty-eight percent of the 87 harvests as sustainable, forty-eight percent as possibly sustainable, and fourteen percent as unsustainable. This assessment confirms the resilience of Pennsylvania's forests, and highlights the opportunity to benefit greatly from improvements in harvesting practice. Assessments rated unsustainable from the outcome perspective had:

- adequate regeneration stocking,
- appropriate levels of residual stocking (i.e., they tended to be either regeneration or intermediate treatments rather than "combined" harvests),
- acceptable numbers of non-commercial and low value species,
- consistent or improved species composition in the residual stand,
- higher amounts of AGS,
- lower amounts of damage to residual stems and crowns, and

- increased use of soil and site protection measures.

In summary, sustainable tracts had a lower stem damage index, less than half as high. Likewise, sustainable tracts had lower amounts of crown damage and more evidence of erosion and sedimentation control measures. Harvests on sustainable tracts removed a lower percentage of large, more valuable trees, retaining more of the options for future treatments. Cutting or tending to reduce USG and to remove non-commercial saplings was more common on sustainable tracts.

Cutting intensity measured as Relative Stand Density (RSD) provides a context for considering the full matrix simultaneously for practice and outcome. Three levels of cutting were: Regeneration (0 - 19% RSD), Intermediate treatments (≥50% RSD), Combined Treatments (20-49% RSD). Combined treatments, because of the cutting intensity, were neither regeneration nor intermediate treatments. The intent of the cutting treatment was uncertain since it did not reflect accepted even-aged silivicultural treatments.

For regeneration harvests (n=19), from the combined perspectives of practice and outcome (i.e., the full matrix), nine were sustainable, nine were unsustainable, and one was possibly sustainable. Only regeneration-related variables differed between sustainable and unsustainable classes

Among intermediate treatments (n=33), again from the combined perspectives of practice and outcome, 27 were sustainable, five were unsustainable, and one was possibly sustainable. Eleven of the 30 variables differed between the sustainable and unsustainable tracts, including erosion and sedimentation pollution control measures, retention of large, high-value timber, and residual tree crown damage.

Using the full matrix for combined harvests (n=33), those with between 20 and 50 percent relative density, accounted for five sustainable, two possibly sustainable, and 26 unsustainable treatments. Sustainable tracts had a higher retention of high quality timber, more evidence of tending, a smaller reduction in average DBH (e.g., 1 inch compared to more than 5 inches) and less fern and grass cover.

THAAT did not compare future condition with desired conditions because of limited time and funding. Analysis of sustainable and unsustainable conditions suggests numerous opportunities and approaches for improving harvesting practices and resultant outcomes. In considering the findings from the study it easier to define improvements before the harvest than it is to remediate the results. Obviously Pennsylvania's forests are resilient, but they do require care, there is a threshold that varies with stands, sites, etc.

The second goal of the project was to recommend policy alternatives and actions for addressing timber resource sustainability. THAAT members identified opportunities

for improving the position of stands within the sustainability matrix, moving them toward the sustainable practice/sustainable outcome cell. The fifteen tables in Appendix F provide an understanding of opportunities for making these adjustments.

Education is key for affecting changes in timber harvesting practices that will increase the likelihood that more of Pennsylvania's timber harvests would be rated sustainable in a subsequent assessment. Traditional landowner and logger education programs supported by the Bureau of Forestry, Penn State extension service, County Conservation Districts, and others provide important information for sustaining the state's timber resource. Specific programs such as the Forest Stewardship Program, the VIPs/Coverts Volunteer Initiative, county forest landowner associations, and other thrusts empower landowners to make responsible decisions.

In the past year the AF&PA began implementation of the Sustainable Forestry Initiative (SFI). The SFI focuses much of the forestry community on a process that can lead to harvesting practice changes that will lead to increased sustainability. SFI is a voluntary program lead by forest industry and depends on the collaboration of others to institute an education program designed for loggers, resource professionals, and forest landowner.

Forest landowner, logger, and resource professional outreach and voluntary use of the state's new *Best Management Practices for Pennsylvania Forests* will do much to address issues found in the THAP that will lead to increased timber sustainability.

Conclusions and Recommendations

THAAT identified opportunities for enhancing timber resources sustainability. These opportunities relate to residual species composition, diameter distributions, residual tree quality, regeneration stocking, interfering plants, site disturbance, and residual tree protection. The BMPs provide guidelines for changing harvesting practices that will make positive changes in harvesting outcomes, moving toward increased occurrence of sustainable timber harvests.

ABSTRACT:

Pennsylvania's even-aged hardwood forests originated from turn-of-the-century harvesting and a wide range of major disturbances. Forests were cleared for agriculture and timber was harvested to furnish a wide array of forest products. Today's vast even-aged forests are 70-90 years old and are rapidly maturing. These forests contain commercially valuable trees demanded both domestically and internationally. Documenting the condition of this forest is essential for understanding the changing nature of the resource, identifying research opportunities, monitoring management processes, and for fostering industry, agency, and education programs to ensure long-term timber resource sustainability. Data collected from a systematic sampling of 97 recently harvested tracts across all ownerships, are used as the basis for evaluating whether and to what extent timber harvesting activities are affecting Pennsylvania's timber sustainability.

The Timber Harvesting Assessment Advisory Team (THAAT) rated tracts using data summaries combined with professional training and experience. The THAAT found that from a crop outcome perspective the forests were in better condition than from a practice perspective, perhaps in part reflecting the forest's resilience. Three major differences distinguished sustainable from unsustainable harvests. Retention of the larger more valuable trees and removal of slower growing, less valuable trees characterized sustainable tracts. Sustainable tracts showed greater care of residual trees. And, sustainable tracts had more erosion and sedimentation pollution control practices. Many of the characteristics leading to tracts rated unsustainable are addressed in *Best Management Practices for Pennsylvania Forests*.

Results characterized only current timber harvesting impacts. Future research would be required to measure changes in timber sustainability.

"THE EFFECTS OF TIMBER HARVESTING ON PENNSYLVANIA FOREST SUSTAINABILITY"

FINAL REPORT:

Project Summary

Pennsylvania's forests are critically important to the state's economy and our quality of life. Covering nearly 60 percent of the Commonwealth, forests protect 25,000 miles of waterways, provide recreation, furnish clean air and scenic beauty, and offer us peace of mind. In addition to sustaining a forest-based recreation and tourism industry, forests also furnish raw materials to a dynamic wood products industry. This manufacturing base including firms ranging from pulp and paper plants to Amish specialty shops, employs 100,000 workers and generates annual sales in excess of $4.5 billion. The economic and cultural vitality of rural Pennsylvania is dependent on the long-term sustainability of Pennsylvania's forests and the diverse industries they support.

At the turn of the century forests were cleared for agriculture, and timber was harvested to furnish a wide array of forest products: white pine for ship masts, hemlock bark for tannins, small roundwood for charcoal (McNeil 1952), and lumber for a growing nation. Following that harvest, fires frequently ravaged the forest. Today's even-aged forests are 70 to 90 years old and rapidly maturing. They contain commercially valuable hardwoods demanded by both domestic and international markets. Documenting the condition of this forest is essential for understanding the changing nature of the resource, identifying research opportunities, monitoring management processes, and for fostering industry, agency, and education programs to ensure long-term resource sustainability.

Non-industrial private forests (NIPFs) account for 75 percent of Pennsylvania's forest land. Estimates are that NIPFs provide 80 percent of the one billion board feet harvested annually in the state. Understanding the condition of these forests as well as those on public lands is essential to the future of the state's forest industry, which will continue to depend on these NIPFs for raw material supply.

The importance of the state's forests was confirmed with the passage of the Pennsylvania Hardwoods Development Council Act in 1988. One of the first actions of the Council was commissioning a comprehensive Needs Assessment (Stanturf 1989). Stanturf observed that the long-term success of the Council's development goal ". . . rests upon the sustainable supply of quality hardwoods." Stanturf believed that we must understand and anticipate resource sustainability issues so that programs can be forged to protect the productivity capacity of Pennsylvania's forestlands. To this end he offered a

specific recommendation to "Survey a sample of recently harvested sites on private ownerships to rate the quality of silviculture being employed. . ."

Harvesting is an essential tool of silviculture. Properly designed harvests can provide economic returns as well as maximize other landowner objectives. Poorly designed harvests may lead to reduction in the quantity and quality of important hardwood species. Leading to future stands with limited management options. Some harvesting approaches do not necessarily ensure long-term sustainability (Jokela and Sawtelle 1985, Smith and Miller 1987, Abrams and Scott 1989). Diameter-limit cuts are ineffective in regenerating oak-hickory and oak species groups (Heiligmann and Ward 1992). The scientific forestry literature demonstrates clearly the consequences of alternative harvesting regimes in forest types common to Pennsylvania (Heiligmann and Ward 1992, Marquis 1979, Carvell and Tyron 1961, and Miller and Smith 1991, Considine et al. 1983).

Renewing commercially desirable speices in Pennsylvania's hardwood forests depends almost exclusively upon advanced regeneration (Marquis et al. 1992). McWilliams et al. (1995) examined 499 sample locations in stands with between forty to seventy-five percent stocking (i.e., partial cuttings) during the course of Pennsylvania's 1989 forest inventory. Causes for these densities may have included timber harvests or natural mortality and no effort was made to group stands by time since disturbance. Among these stands, depending upon the regeneration requirements used, only six to twenty-eight percent of the stands were adequately stocked with advance regeneration of commercial species, and only four to eleven percent of the stands were adequately stocked with advance regeneration of commercially desirable species.

Project Scope

This timber harvesting assessment, is based on the assumption that high-quality sawlogs are important and will remain essential to sustain the state's forest industry. While "trees" are important to the pulp and paper, oriented strand board, particleboard, and associated industries, high-quality sawlogs provide the economic returns and incentives for most timber harvesting. Ensuring that these forests provide resources for today and tomorrow is important to the public, forest landowners, and forest industry. The focus of the Timber Harvest Assessment Project (THAP) was on timber.

The American Forest and Paper Association (AF&PA), a national trade group that represents over 400 forest and paper companies, through the Sustainable Forestry Initiative (SFI), offers a definition of sustainable forestry. Sustainable forestry means

"managing our forest resources to meet the needs of the present without compromising the ability of future generations to meet their own needs by practicing a land stewardship ethic which
integrates the growing, nurturing, and harvesting of trees for useful products with the conservation of soil, air, and water quality, and wildlife and fish habitats" (AF&PA 1995).

Forest Sustainability as offered by the AF&PA encompasses all benefits attained through forest management. The THAP narrowed the focus to timber because assessing the broad scope of forest sustainability was considered beyond the scope of their expertise. The essential protocol and metric for evaluating even timber sustainability were non-existent. Ultimately sustaining timber resources through active management will protect and sustain many of the other values addressed in the AF&PA definition.

Project Goals and Objectives

The project had two main goals: Determine whether and to what extent current timber harvesting practices are affecting Pennsylvania's timber resource sustainability; and, recommend policy alternatives and actions for addressing the situation.

Assessing the effects of current harvesting on timber resource sustainability includes five objectives:

1) Create a Timber Harvesting Assessment Advisory Team.
2) Develop detailed assessment protocol.
3) Collect data sufficient to draw conclusions regionally and by ownership.
4) Analyze the results, establish baseline conditions, and project consequences of current practices
5) Identify future resource conditions.

Developing policy alternatives encompassed four objectives:

1) Compare projected future conditions to desired conditions.
2) Determine whether modifications to current practices are necessary to reach desired conditions.
3) Develop alternative policy and actions initiatives for achieving the desired conditions.
4) Recommend preferred alternatives.

Procedures

The first project goal was to determine whether and to what extent current timber harvesting practices are affecting Pennsylvania's timber resource sustainability. To develop measurement protocol and metric for conducting the research, a group of natural resource professionals, the Timber Harvesting Assessment Advisory Team (THAAT, Appendix A) was assembled. THAAT aggressively sought and secured additional funding and support (Appendix B), expanding on CRP base funds. THAAT members represented a wide range of professional employment, experience, and education, including forest industry, private forestry consulting, US Forest Service, Pennsylvania Bureau of Forestry, Pennsylvania Game Commission, and Penn State University. THAAT also solicited and received advice and input from Drs. Ralph Nyland and Mary Ann Fajvan, faculty members at State University of New York, College of Environmental Sciences and Forestry, and West Virginia University, respectively.

Development of the assessment protocol started well before the 1995 field season. Refining site selection protocol suggested by Ralph Nyland, a subcommittee of THAAT established guidelines for locating assessment harvests (Appendix C) and a metric for conducting the assessment at the chosen sites (Appendix D).

Timber harvests selected for evaluation were harvested between April 1, 1992, and March 30, 1994. This window of time provided tracts that were too old to contain spanworm related mortality and were too new to show gypsy moth related mortality from severe defoliation of the early and mid-1980s.. Tracts would have to cover a minimum of 8 acres to accommodate the plot design. Ownership data were collected, but were not used in determining timber sustainability. All private owners of assessment locations gave permission, with an assurance of anonymity, for entering their land for conducting the survey; following university protocol their names and property locations were not released.

Individual assessment sites were located using USGS topographic sheets. Pennsylvania is covered by 980 topographic sheets. Topographic sheets with more than 50 percent of their coverage outside the state and those with more than 60 percent urban were excluded from the sample. Using data on harvesting intensity (Alerich 1988) the eight US Forest Survey units were combined to form three sampling units for the assessment. Ultimately 100 topographic sheets distributed according to harvesting intensity were randomly selected and Bureau of Forestry service foresters identified potential assessment sites using selection protocol.

During the 1995 field season 97 sites received evaluations. Seventy-three sites were on private ownerships (i.e., 72 on non-industrial private forests (NIPFs) and 1 on

forest industry). Public ownerships accounted for 24 assessment sites (i.e., 2 Allegheny National Forest, 11 Pennsylvania Game Commission, and 11 Pennsylvania Bureau of Forestry). Each of the NIPF owners received a mail survey to determine their objectives, the role of a forester in the harvest, and other information relative to the harvesting decision and its outcome. Nearly 60 percent of the NIPF owners responded to the survey; however, this data has not been analyzed.

Both New York and West Virginia undertook timber harvesting assessments similar to Pennsylvania's. New York began collecting data in 1994 using volunteers from the state's Division of the Society of American Foresters. To date they have completed about 60 assessments and plan on completing 100 sites. West Virginia collected data during the 1995 field season, completing 104 assessments that year. Researchers in each state believed that the sampling scheme assured an acceptable level of confidence to draw conclusions from a sample size approaching 100 sites. Obviously New York is not ready to evaluate their data and West Virginia's sustainability classification was delayed because of an extended leave of absence for the principle investigator.

The metric established to assess timber sustainability fully described in Appendix D depends heavily on existing research, and inventory-based protocol. The information collected focused on the existing condition of the site, overstory and understory vegetation, and provided data for constructing pre-harvest conditions (Appendix E). Determining pre-harvest conditions was essential because it provided the benchmark against which treatment results were compared. Ultimately the findings reported here depended on:

- Species — the proportion of high value (e.g., oaks, white ash, black cherry, and sugar maple), medium value (e.g., red maple, and yellow poplar), low value (e.g., any species of commercial value not in high and medium), and non-commercial species (e.g., all non-commercial species). Again, the focus was on timber, thus maintenance of preferred species was important. Harvesting operations should maintain or improve species composition, moving a stand toward higher amounts of high and medium value species.
- Quality — considered suitability of residual trees for developing sawlog potential. Commonly trees are classified as Acceptable Growing Stock (AGS) and Unacceptable Growing Stock (UGS). These condition classes refer to stem quality and defects. Only residual trees could be assessed for quality. The relative proportion of AGS to UGS in the stand serve as an indication of tending by cull removal to improve residual tree quality.

- Diameter Distribution — all residual trees greater than 1 inch diameter breast height (DBH) were tallied. All stumps were also measured and DBH estimated for all harvested trees. The resulting data established pre- and post-harvest diameter distributions for the site and by species. Shifts in diameter distribution along with information on species composition, basal area, and relative density help define the type of harvest and silvicultural treatment.
- Regeneration — focuses on stocking levels for species classes (i.e., high, medium, and low value). Data on seedling size, probable winners in each of the sample locations, measures of competition from interfering plants were also gathered. This information evaluated against research findings designed to evaluate pre-harvest conditions and blended with experience provides benchmarks for judging regeneration success.
- Site Disturbance — the amount of the site disturbed, the use of erosion and sedimentation control practices, and depth of rutting describe the care given the site. Statewide averages were compared to individual site values for aiding in the assessment.
- Tree Damage — square inches of stem damage on the first log and the proportion of the crown damaged on residual trees served as an index. Index values compared to statewide averages served as a criterion for interpretation.

Examples of data summaries are given in Appendix E. A series of summary tables and charts provide information about pre-and post-harvest stand conditions derived from the variables described above. SILVAH runs on pre- and post-harvest data provided an additional data summary for THAAT.

Data Analysis

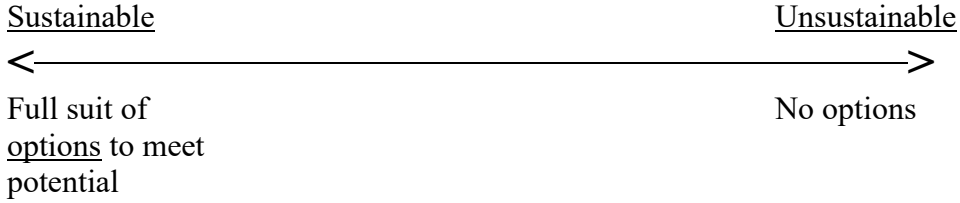
For more than a year the THAAT met at least every two months to develop consensus on procedures for analyzing the data. This included selecting the variables described above from the data set, developing summary tables, and working to achieve shared understanding about interpreting the information. It was an exchange process whereby individuals openly discussed their opinions, shared observations, and shifted their perspectives to develop a process for analysis that was both rigorous and objective.

A key element in this process is contained in the AF&PA definition of forest sustainability — ". . . without compromising the ability of future generations." To the THAAT members this lead to the principle that the opportunities or options of the landowners or managers to manage a stand to meets its full potential should not be

compromised by the harvest. Potential is a measure of productivity and contains two elements, site and trees. Therefore the harvest should not degrade the site nor adversely affect tree quality, species composition, or potential. In a word the potential is the ability of the stand to produce the full complement of options.

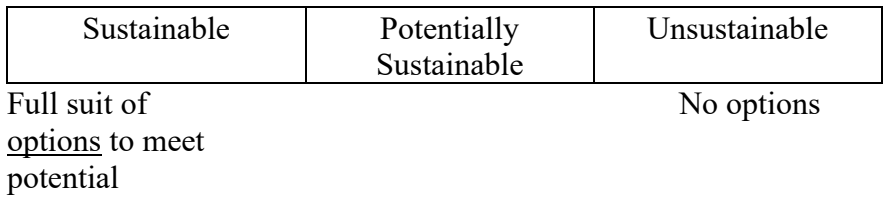
The working definition of sustainability for the THAAT was this potential. Data collected in the assessment allowed for reconstructing the pre-harvest stand. The pre-harvest stand condition became the measure of potential or the benchmark against which sustainability was measured. Importantly many stands examined in the assessment had been entered at least once before the assessment. This cutting activity did modify the stand, thus the benchmark may or may not represent the full potential of the site. Nonetheless, in principle there exists a set of conditions along a continuum from sustainable, where the full suit of options exists to meet potential, to unsustainable, where very limited options exist. Along this continuum, depending on one or more of the assessment variables, the predicted outcome becomes uncertain and the treatment was judged possibly sustainable.

Figure 1. A spectrum of conditions for measuring sustainability



Working within the framework of a continuum made it difficult to define timber sustainability and the THAAT recognized that there are flexible boundaries that define three levels: sustainable, potentially sustainable, and unsustainable (Figure 2).

Figure 2. Sustainability boundaries along the spectrum of condition for measuring sustainability.



Using the conceptual model described in Figure 2, the THAAT evaluated 40 harvest sites. This model often lead to incongruities in interpreting the data. Stands would appear sustainable, but clearly the treatments that brought about the outcome were not sustainable. An example would be a harvest that had sufficient residual stocking, but the species composition and average DBH had been significantly changed, an obvious high-grade.

A visiting scientist from England, Gary Kerr, suggested that the evaluation process had two components. The components were the process used to attain the existing condition and the outcome itself. These became the practice and the outcome (Figure 3). Outcome relates to the degree to which timber management options remain: sustainable, all options remain; possibly sustainable, some options remain; and unsustainable, virtually not options remain. Practice relates to the level of silviculture used and the nature of the forest operations employed (e.g., erosion and sedimentation pollution control): sustainable, sound silvicultural operations and management; possibly sustainable, some silviculture and management; unsustainable, virtually no silviculture and management. The resulting matrix contains nine cells. The THAAT concluded that two cells were null — representing incongruent results — as indicated by the shading in Figure 3. At this juncture it was necessary to start over again, applying the new two dimensional matrix to each of the completed stands as well as the 57 not evaluated.

Figure 3. Timber resource sustainability matrix for practice and outcome.

Practice \ Outcome	Sustainable	Possibly Sustainable	Unsustainable
Sustainable	s/s	s/ps	
Possibly Sustainable	ps/s	ps/ps	ps/u
Unsustainable		u/ps	u/u

Cutting intensity was an important variable for considering several of the assessment criteria, including diameter distribution, species composition, and obviously, regeneration. Using THAAT experience and existing research, THAAT set limits for

residual relative stand density that defined cutting intensities and associated silvicultural outcomes (Figure 4). Combined harvests were obviously neither regeneration harvests nor intermediate treatments. Combined harvests were characterized as having truncated diameter distributions, suggesting diameter-limit based harvests, shifts in species composition, little thinning or tending in the residual trees, and higher percentages of UGS in the residual stand.

Figure 4. Cutting intensities and associated silvicultural outcomes.

		Number of Tracts
0–19% RSD	Regeneration	19
20–49% RSD	Combined	38
≥50% RSD	Intermediate	40
	Total	97

Results

The THAAT, using data summaries and open discussion about placement of individual harvests in the sustainability matrix, achieved at least 50 percent agreement on up to 88 of the 97 tracts, depending on context of question (i.e., from a practice or outcome perspective). The results of the 97 tract evaluations were compiled into fifteen tables by their sustainability classification and cutting intensities. Thirty variables were then examined, along with their corresponding significance levels (alpha 0.10) (Appendix F).

Two matrices provide a quick and relevant summary of the findings from the outcome and practice perspectives. Figure 5, provides a practice perspective for 87 tracts that attained at least 50 percent THAAT agreement. Twenty-five percent of the assessments received sustainable ratings, while more than 40 percent were classified as unsustainable and an additional 30 percent are possibly sustainable. The THAAT placed tracts into the matrix using data summaries and personal experience and knowledge. The statistical analyses presented in Appendix F, Tables 4, 5, and 6 support the separations between sustainable, possibly sustainable, and unsustainable treatments and the generalized summary that follows. Sustainable practices tended to:

- maintain or improve the tree species composition,
- suggest control other than diameter limits were used select trees for harvest,
- retain more AGS to UGS in the residual stand,

- show more cutting or tending in all diameter classes,
- establish and where necessary release regeneration,
- install soil erosion and sedimentation pollution control practices, and
- protect residual trees from stem and crown damage.

Figure 5. Timber resource sustainability from a practice perspective.

Practice			
	Sustainable	n=22 (25%)	
	Possibly Sustainable	n=28 (32%)	
	Unsustainable		n=37 (43%)

Figure 6 presents the assessment findings from the outcome perspective. Clearly the percentage of plots classified as sustainable is larger than from the practice perspective (25% vs. 38%). Nearly half of the assessments received possibly sustainable ratings and less than 15 percent were rated unsustainable. Again, the THAAT placed tracts into the matrix using data summaries and personal experience and knowledge. The statistical analyses presented in Appendix F, Tables 7, 8, and 9 support the separations between sustainable, possibly sustainable, and unsustainable treatments and the generalized summary that follows. Assessments rated sustainable from outcome perspective had:

- adequate regeneration stocking,
- appropriate levels of residual stocking (i.e., they tended to be either regeneration or intermediate treatments rather than "combined" harvests),
- acceptable numbers of non-commercial and low value species,
- consistent or improved species composition in the residual stand,
- higher amounts of AGS,
- lower amounts of damage to residual stems and crowns, and
- increased use of soil and site protection measures.

Figure 6. Timber resource sustainability from an outcome perspective.

Outcome

Sustainable	Possibly Sustainable	Unsustainable
n=34 (38%)	n=42 (48%)	
		n=12 (14%)

The First Project Goal

The first project goal was to determine whether and to what extent current timber harvesting practices are affecting Pennsylvania's timber resource sustainability. Ninety-seven tracts were examined to address this goal. The THAAT was able to classify, using 50 percent or higher agreement, up to 88 tracts.

The THAAT chose to summarize the assessment results in several ways. One of these was to merge placements in adjacent cells. Figure 7 depicts a summary matrix where three groups were developed showing the classification of 85 tracts. Groups 1 contains sustainable practices and outcomes as well as possibly sustainable outcomes or practices, every cross tabulation in this group has a sustainable element. Group 2 while it contains possibly sustainable outcomes and practices always contains an unsustainable classification in the cross tabulation.

Figure 7. Group 1 and Group 2 summaries of the sustainability matrix.

		Outcome		
		Sustainable	Possibly Sustainable	Unsustainable
Practi	Sustainable	Group 1 n=41		
	Possibly Sustainable		Possibly Sustainable n=4	

c e	Unsustainable		Group 2 n=40

Evaluation of the plots depicted in Figure 7 finds that Group 1 sites (Appendix F, Table 10) had a lower stem damage index, less than half (0.8 compared to 1.9). Likewise Group 1 tracts had lower amounts of crown damage and more evidence of erosion and sedimentation pollution control measures. Harvests on Group 1 sites removed a lower percentage of large, more valuable trees, retaining more of the options for future treatments. Only half of the high value trees 18" DBH and greater were harvested on Group 1 treatments, while all were taken on Group 2 harvests. In addition harvests on Group 1 tracts retained more of the high value trees in the 12 to 18" DBH class. Cutting or tending to reduce UGS and to remove non-commercial saplings was more common on sustainable tracts.

Matrices forming Group 1 and Group 2 summaries for regeneration harvests and intermediate and combined treatments were similarly created. Again, the purpose of these matrices was to permit easier interpretation of assessment findings. The next three paragraphs address these three specific matrices which are shown in Appendix F.

For regeneration harvests (n=19), those that retained from 0 to 19 percent relative density, nine were placed in Group 1, nine were Group 2, and one was possibly sustainable. Only regeneration-related variables differed between sustainable and unsustainable classes (Appendix F, Table 11).

For intermediate treatments (n=33), those that retained 50 percent or more relative density, 27 were in Group 1, five were placed in Group 2, and one was possibly sustainable (Appendix F, Table 13). Eleven of the 30 variables differed between the Group 1 and Group 2 tracts, including erosion and sedimentation pollution control measures, retention of large, high-value timber, and residual tree crown damage.

Combined harvests (n=33), those having between 20 and 50 percent relative density, accounted for five Group 1 placements, two possibly sustainable, and 26 Group 2 harvests (Appendix F, Table 12). Group 1 tracts had a higher retention of high quality timber, more evidence of tending, a smaller reduction in average DBH (e.g., 1 inch compared to more than 5 inches) and less fern and grass cover.

THAAT did not compare future condition with desired conditions because of limited time and funding. Analysis of sustainable and unsustainable conditions suggests numerous opportunities and approaches for improving harvesting practices and resultant

outcomes. In considering the findings from the study it easier to define improvements before the harvest than it is to remediate the results. Obviously Pennsylvania's forests are resilient, but they do require care, there is a threshold that varies with stands, sites, etc.

The Second Project Goal

The second goal of the project was to recommend policy alternatives and actions for addressing the timber resources sustainability. THAAT members identified opportunities for improving the position of stands within the sustainability matrix, moving them toward the sustainable practice/sustainable outcome cell. The fifteen tables in Appendix F provide an opportunity for making these adjustments.

Education is key for affecting changes in timber harvesting practices that will increase the likelihood that more of Pennsylvania's timber harvests would be rated sustainable in a subsequent assessment. Traditional landowner and logger education programs supported by the Bureau of Forestry, Penn State extension service, County Conservation Districts, and others provide important information for sustaining the state's timber resource. Specific programs such as the Forest Stewardship Program, the VIPs/Coverts Volunteer Initiative, county forest landowner associations, and other thrusts empower landowners to make responsible decisions.

Importantly, the AF&PA SFI focus much of the forestry community on a process that can lead to harvesting practice changes that will increase sustainability. SFI is a voluntary program lead by forest industry and depending on the collaboration of others to institute an education program designed for loggers, resource professionals, and NIPF owners.

Part of the SFI landowner education program is a shared understanding that landowners require information to empower them to make informed decisions about the future of their forests. To this end every landowner considering a timber harvest will receive information designed to help them ask questions and obtain guidance for sustaining their forest.

SFI has chosen to embrace Pennsylvania's newly released Best Management Practices (BMPs) as a minimum level of commitment by timber harvesters practicing sustainable forestry. The publication written by a Forest Issues Working Group Task Force provides basic information about forest management and BMPs for planning, forest operations, including regeneration and renewal, and tending, and forest values (i.e., aesthetics, wildlife, and species and habitats of special concern). Voluntary use of these

BMPs will do much to moving more of Pennsylvania's harvests toward sustainable conditions.

Conclusions and Recommendations

THAAT identified opportunities for enhancing timber resources sustainability. Properly designed and executed timber harvests can provide economic return supporting the state's forest industry as well as maximize landowner objectives. Silviculture focuses on tending or intermediate treatments and regeneration. Intermediate treatments for timber production retain or improve species composition and quality, control diameter distributions and tree spacing, protect residual trees, protect the site, and where necessary look forward to control interfering plants and to provide for advanced regeneration. Regeneration harvests use knowledge of site variables, silvics, and prevailing conditions that may delay or prevent regeneration to design prescriptions.

Non-silvicultural treatments, such as diameter limit cutting or high-grading (i.e., taking only the high-quality or high-value trees), do not consider future conditions. While these types of harvests may maximize immediate returns they do not necessarily address sawtimber sustainability. The site data evaluated by the THAAT suggest that many of the unsustainable harvests are of this type. Focusing on the condition of the residual stand rather than removals can improve this situation. Imparting or reinforcing an understanding of stand development and dynamics to timber harvesters, landowners, and resource professionals will improve practices and lead to more frequent sustainable outcomes.

The SFI, the Pennsylvania Forest Stewardship Program, and Cooperative Extension are already incorporating elements of the findings in education and outreach efforts. SFI is developing education programs for loggers, encouraging them to use better harvesting techniques. The recently released BMPs for Timber Harvesting Practices in Pennsylvania provide guidelines for changing harvesting practices that will make positive changes in harvesting outcomes, moving toward increased occurrence of sustainable timber harvests.

Opportunities for Further Research

The THAP project raises additional questions related to timber harvesting assessments and information needs for guiding forest management in Pennsylvania. The following objectives and potential products were developed by a small group of resource professionals and industry representatives interested in exploring research and education

questions and opportunities arising from the THAP. It is their intent that these ideas might serve to direct work in timber harvesting assessment.

Objective 1: Describe regeneration patterns across the state.

Product 1: Base data for gauging Sustainable Forestry Initiative (SFI) implementation

Product 2: Base data for influencing white-tailed deer management policies

Objective 2: Describe the patterns of sustainability across the Commonwealth using various biological and socioeconomic factors.

Product 3: Hypotheses for other studies and interim forest management guidelines. An analysis of treatment costs for working with existing stands classified as combined treatments by THAAT I (20-49% relative stand density).

Product 4: Data for developing studies and preliminary management guidelines for stands that have two-aged structure.

Objective 3: Develop a metric for determining forest operation sustainability, pre- and post-harvest.

Product 5: A metric for conducting self- and third-party assessments.

Product 6: A revised self- and third-party assessment form.

Product 7: A methodology for gauging sustainability building on the THAAT analysis, reducing staff and time requirements.

Objective 4: Describe the long-term effects of both sustainable and unsustainable forest operations on timber and wildlife.

Product 8: Description of cost effective regeneration and tending activities, both during and after a forest operation.

Product 9: Simulation processes for understanding activity effects on timber and wildlife resources at both the stand and landscape levels.

Objective 5: Determine how and why landowners make decisions regarding forest management.

Product 10: A strategy for information and technology transfer to enhance landowner decision making, including strong cooperation with SFI.

Product 11: Policy options to motivate longer-term management (e.g., taxes, estate planning, legislative).

Articles Generated by the Project

A major outlet for project results and findings will be the series of magazine and journal articles described below:

Article #1

A three page article was printed in *Pennsylvania Forests* in the summer of 1996 (Appendix G). The article gives a brief overview of the project and discusses the involvement and cooperation of the Timber Harvesting Assessment Advisory Team (THAAT). A brief introduction provides a past history of Pennsylvania's forests and their uses. The article reviews the current trend towards increased timber harvesting around the state as the demand for high quality hardwood sawlogs both domestically and internationally increases. The article defines the six forest resource assessment criteria: species composition, diameter distribution, tree quality, regeneration, site disturbance, and tree damage, and describes their relevance to sustainability. The article offered the public a first look at the project and the THAAT committee and the funding agencies and organizations cooperated.

Article #2

A manuscript will be submitted to the *Northern Journal of Forestry* in the winter of 1997. The article will review the project from creation of the Timber harvesting Assessment Advisory Team (THAAT) through analysis of the 97 tracts. The article will not present results, but will focus on the process of collecting and analyzing the data. The article will describe the rationale for conducting the study and examine the collaboration efforts of THAAT. It will present methodology, including the process of randomly selecting 7.5 minute quadrangle sheets by proportional regional harvest levels. The manuscript will detail the in-kind contributions of various partners, including the Bureau of Forestry's major effort to locate candidate tracts. Another important facet is THAAT's effort to design a data collection scheme that would provide data to assess

timber resource sustainability. We'll present the six timber resource assessment criteria. Our purpose is to introduce forestry and related professions to this unique collaborative effort.

Article #3

A manuscript will be submitted to the *Journal of Extension* in spring 1997, focusing on the role that Penn State's Forestry Resource Extension faculty played in developing and leading the project. The cooperative effort among Penn State, state and federal agencies, forest industry, and private consultants will be discussed, including formation of the Timber Harvesting Assessment Advisory Team (THAAT). An important facet is relating how extension can meet the pressing concerns of today's forestry community in a science-based, non-judgmental, and decisive manner. We'll focus on the educational aspects and opportunities brought about by the project. The initial audience is Extension and other natural resource educators.

Article #4

A fourth article will be written for the *Journal of Forestry*, summer of 1997. The article will discuss tri-state collaboration among Pennsylvania, New York, and West Virginia. We'll address current timber harvesting practices and their effect on the region's timber resources. If results from the three state assessments warrant, we will develop recommendations for achieving timber resource sustainability. The primary audience will be natural resource professional from across the United States.

Literature Cited:

Abrams, M.D., M.L. Scott. 1989. Disturbance-Mediated Accelerated Succession in Two Michigan Forest Types. *Forest Science*. Vol 35. pp. 42-49.

Alerich, C.L. 1993. Forest Statistics for Pennsylvania -- 1978 and 1989. USDA Forest Service, NE Forest Experimentation Station. Resource Bulletin NE-126.

American Forest & Paper Association. 1995. Sustainable Forestry Initiative Implementation and Guidelines. April 1, 1994. Washington, DC.

Carvell, K.L., E.H. Tyron. 1961. The Effect of Environmental Factors on the Abundance of Oak Regeneration Beneath Mature Oak Stands. Forest Science.

Considine, Thomas J. and Joseph E. Bernard. 1983. Current Structure of Pennsylvania's Forest Lands as it Relates to Future Regeneration. In Proc. Regenerating PA's Hardwood Stands. p.p. 35.

Heiligmann, Randall B., Jeffrey S. Ward. 1992. Hardwood Regeneration Twenty Years After Three Distinct Diameter-limit Cuts in Upland Hardwoods. In Proc. 9th Central Hardwoods Conference.

Jokela, J.J., R.A. Sawtelle. 1985. Origin of Oak Stands on the Springfield Plans; a Lesson in Oak Regeneration. In Proc. Central Hardwoods Forestry Conference.

Marquis, D.A. 1979. Shelterwood Cutting in the Allegheny Hardwoods. *Journal of Forestry*. Vol 77, No. 3.

Marquis, D.A., R.L. Ernst, S.L. Stout. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (revised). USDA, For. Serv. Gen. Tech. Rep. NE-96. 101p.

McNeil, J.H. 1952. The Charcoal Burning Industry. Pennsylvania Forests and Water. 4(1) p.p. 4.

McWilliams, W. H. 1995. Adequacy of Advanced Tree-Seedling regeneration in Pennsylvania's Forests. *Northern Journal of Applied Forestry*. Vol 12, No. 4.

Miller, Gary W., Clay Smith. 1991. Comparing Partial Cutting Practices in Central Appalachian Hardwoods. 8th Central Hardwoods Forest Conference.

Smith, H.C., B.W. Miller. 1987. Managing Appalachian Hardwood Stands Using Four Regeneration Practices - 34-year Results. *Northern Journal of Forestry*. Vol 4., pp. 180-185.

Stanturf, J.A. 1989. Needs Assessment Report to the Pennsylvania Hardwoods Development Council. Penn State School of Forest Resources.