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Forest Policy and Economics xx (2003) xxx–xxx

Forest Policy and Economics

www.elsevier.com/locate/forpol

Economic and ecological impacts of wood chip production in North Carolina: an integrated assessment and subsequent applications

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Received 31 October 2002; received in revised form 23 April 2003; accepted 23 April 2003

Abstract

The North Carolina Wood Chip Mill Study represents an integrated assessment of the economic and ecological impacts associated with production of wood chips at satellite chip mills in the state of North Carolina (NC), USA. Mandated by the Governor of NC, the study was attended by a high degree of public scrutiny. We report principal findings, and describe the processes by which we dealt with uncertainty resulting from limited data availability, methods used to foster public involvement and efforts to reconcile public concerns over forest harvests with our narrower mandate to examine chip mills. We considered the hypotheses that chip mills fostered widespread industrial clearcutting, increased utilization of previously noncommercial timber (especially small hardwoods), depleted future growing stocks of sawtimber, and might create adverse ecological consequences or impair aesthetics important to recreational forest users. NC wood-based industries are a major component of the state's economy, but lagged the state in economic growth from 1977 to 1996. Over the same period, the nature-based tourism sector grew rapidly. Forest land losses in North Carolina from 1982 to 1997 totaled more than one million acres. We used an econometric model to adjust timber land base and project timber supply dynamics to 2020. The simulation indicated that softwood removals exceeded growth from 1990 onward. Hardwood removals exceed growth by 2005, causing inventory levels to decline slightly by the end of the projection period. Wood chip mills processed approximately 27% of the state's chipwood harvest and 12% of the state's total timber harvest. They were statistically correlated with increased timber harvests in the state, especially in the Piedmont and the Mountains. Chip mills have effective storm water management plans and do not show visible signs of adversely affecting water quality. Higher levels of timber harvest alter forest

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1389-9341/03/$ - see front matter
doi:10.1016/S1389-9341(03)00029-7

structures in the Coastal Plain and Piedmont, generally creating less habitat for bird, amphibian and reptile species of conservation concern. Fewer species are adversely affected in the Mountains. Public opinion about chip mills is polarized, and controversy exists principally in the western portion of the state. Overall, public acceptance of study findings was favorable, and selected elements of the research findings have been used to support a variety of advocacy positions.

Keywords: Environmental assessment; Forest resources; Chip mill; Timber harvest; North Carolina

1. Introduction

In May of 1998, the Southern Center for Sustainable Forests (SCSF) initiated a study to evaluate the economic and ecological impacts associated with production of wood chips at satellite chip mills in the state of North Carolina. The integrated study was undertaken at the request of the North Carolina Department of Environment and Natural Resources (DENR), to address public concern for the sustainability of forests within the state; to examine the balance of forest use among environmental, recreational and industrial objectives; and to evaluate the potential of wood chip mills to negatively impact the ecology or the sustainability of North Carolina forests. The SCSF is a collaborative research program with DENR, North Carolina State University, and Duke University as participants.

Several concerns motivated the study. It was hypothesized that chip mills caused increased levels of harvest within the state and fostered widespread industrial clearcutting. It was further hypothesized that by increasing the utilization of previously noncommercial timber and timber residues (e.g. tops, branches, small diameter hardwoods) the chip mills might deplete future growing stocks of the hardwood sawtimber important to North Carolina's furniture industry, or might result in qualitative changes in post-harvest forest condition at logging sites, which, in turn, might have adverse ecological consequences.

The research conducted by the SCSF to address these concerns represents a novel case study in several ways. Conceptually, the project raised the question of whether it was either possible or appropriate to isolate one technological component of a larger industry in order to assess marginal impacts. Methodologically, the broad scope of the study created challenges integrating ecological, economic and social elements. Politically, the study was subject to a level of ongoing public scrutiny not common to scientific research, and was molded in significant ways by both structured and spontaneous interactions with various stakeholder groups.

In this article, we report on the findings of the two-year study, concluded in Fall of 2000. Specifically, we describe the processes employed to integrate the various scientific components, the organizational approach to public involvement and the subsequent uses of the study in policy analyses and development in North Carolina and the South.

The study was characterized by reliance on interdependent data and models of economic and ecological effects. This created an interdisciplinary and synergistic research context. Communication with the public and with stakeholders was structured to facilitate a free exchange of ideas and transparency. Our approach to the presentation of research outcomes was characterized by a continuum from certain findings of fact to more speculative conclusions characterized by a high degree of uncertainty (Mahlman, 1997). The study resulted in the publication of an integrated executive summary of research conclusions (Cubbage et al., 2000a), and in 11 associated reports on individual study components (Cubbage et al., 2000b). It also led to an associated study on aquatic impacts (Schaberg, 2002). The entire wood chip mill report is available at the SCSF web site (http://www.env.duke.edu/scsf/).

2. Methods

The North Carolina wood chip mill study was designed as an integrated technical study with a substantial amount of public input into study

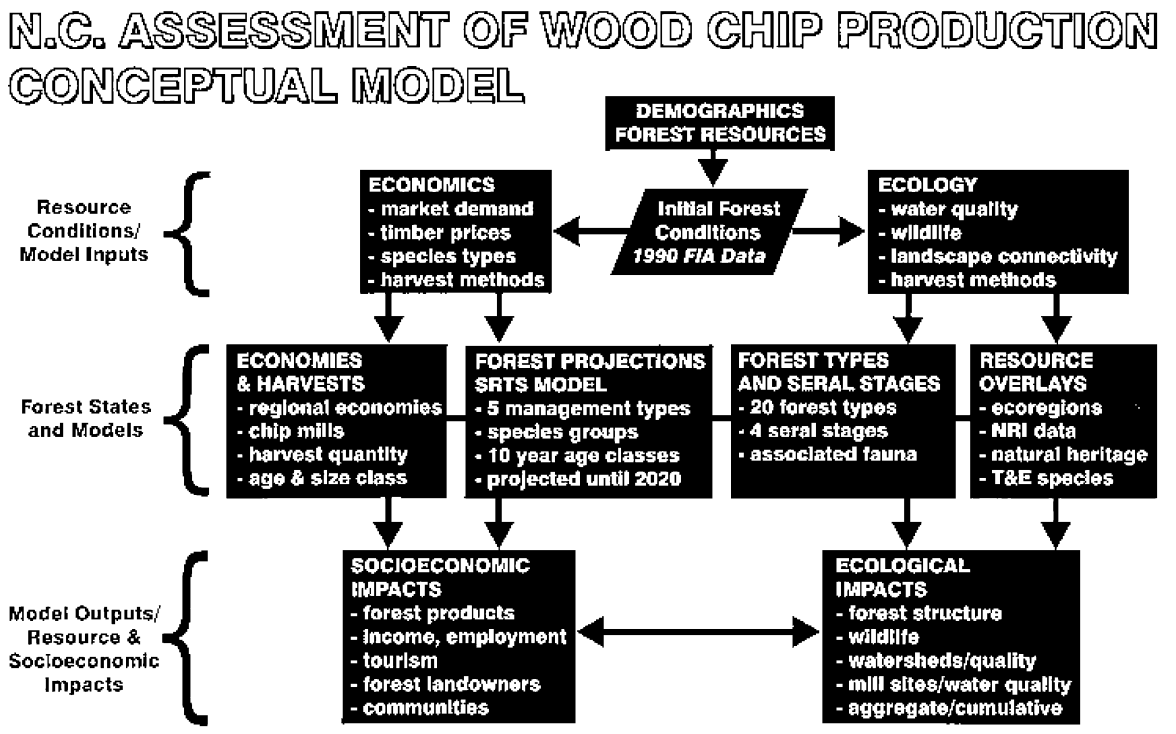

Fig. 1. A conceptual model of the elements of the NC Wood Chip Mill Production Study.

development and execution. As the study proceeded, objectives and methods were modified in response to many questions or suggestions from the study advisors and input at public meetings.

2.1. Public input

We developed an initial study plan after public scoping meetings held during 1997 and 1998. The plan was reviewed by agencies within NC DENR and circulated for public comment. The Natural Resources Leadership Institute (NRLI) at North Carolina State University organized and administered ongoing public involvement throughout the course of the study. A Wood Chip Study Advisory Committee was formed, including members drawn from a variety of stakeholder groups. This advisory committee met monthly to discuss design issues with the research team during the study's initial 6 months, and held two subsequent advisory meetings to review and discuss preliminary findings with the research team. Representatives of the state's various resource agencies also served as technical advisors to the Study Advisory Committee.

NRLI organized a series of public forums, including three open public meetings (two in western North Carolina, one in the eastern portion of the state) to discuss study elements and approaches. In addition, an open public meeting was held at the conclusion of the analysis period in order to present study results and to receive early comments on study findings from the public at large. These comments were incorporated into the final draft of the study findings.

2.2. Study components

The study was organized into three broad components, including an analysis of forest resources and timber market effects, analysis of ecological effects and analysis of social and regional economic effects (Fig. 1). Using a combination of the approved study plan, the technical advisory and

Table 1
The organizational structure of working papers comprising the North Carolina wood chip mill report: *economic and ecologic impacts associated with wood chip production in North Carolina*

Forest resource status and trends
(1) North Carolina's forests 1938–1990
(2) Trends in North Carolina timber product outputs, and the prevalence of wood chip mills
(3) Potential wood chip mill harvest area impacts in North Carolina
(4) Forest resource trends and projections for North Carolina
Ecological impacts
(5) Soil and water effects of modern forest harvest practices in North Carolina
(6) Trends in forest composition and size class distribution: implications for wildlife habitat
(7) Chip mills effects on volume of post-harvest downed woody debris
(8) Storm water and process water management at North Carolina wood chip mills
Economic and social impacts
(9) NIPFs: an analysis of changes in potential returns as a result of shifts in demand
(10) Regional economic impacts of forest products and tourism sectors in North Carolina
(11) Social impact assessment: social impacts and community concerns

state agency input and the public comments, the study team identified 11 components as organizing themes for the analysis (Table 1).

The forest resource component of the study used available data to assess forest resource conditions, land area change and timber product outputs. These analyses were used to inform estimates of timber harvest by subregion within the state and to initialize an econometric model of timber supply and harvests that was used to project forest conditions until 2020 and to compare projected changes with forest conditions in 1990. We assumed that timber harvest rates in North Carolina would increase approximately 1% per year, which was less than historical trends for the 1990s, but reflected current depressed forest products markets. We also addressed forest inventory impacts near new mills.

The ecological component of the study examined soil erosion rates, secondary data on water quality, primary data assessing storm water runoff practices at wood chip mills and an evaluation of residual forest biomass on harvest sites with and without chip mill components. Additionally, results from the timber economics model were used to create ecological models and wildlife habitat analyses of future forest conditions that might result from alternative harvest scenarios.

Related analyses examined timber market structure in the state of North Carolina, trade-offs in benefits between the nature-based tourism sector and the timber industry sectors of the state economy, economic benefits generated by wood chip markets for private forest landowners and concerns of community members near mills.

2.3. Data and models

We relied extensively on the use of existing data and current or newly developed modeling approaches. For each subcomponent, published studies available in the scientific literature were reviewed and relevant findings were summarized. Data sets from prior economic and ecological research were integrated where appropriate to yield new insights relevant to the analysis of wood chip mills. Existing computer models and programs were used to analyze the conditions and prospective changes in North Carolina's forests and regional economic conditions. Additionally, a limited amount of new data was collected. These included data on woody debris at sites with and without a wood chip mill harvest component (Hess and Zimmerman, 2000). We also collected primary data in the community impact assessment component of the study (Warren, 2000).

The most comprehensive data on North Carolina's forests come from the USDA Forest Service's periodic inventory, the Forest Inventory and Analysis (FIA). The principal source for the status of

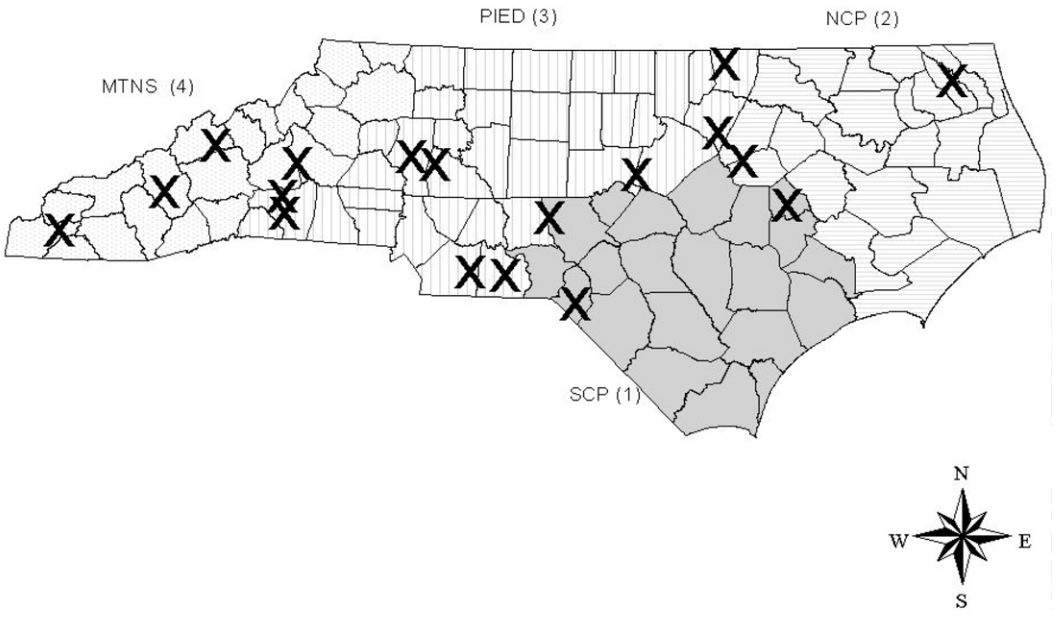

Fig. 2. North Carolina USDA Forest Service FIA reporting regions and locations of satellite wood chip mills (designated by Xs).

North Carolina's forests are the relatively old 1990 FIA data (Brown, 1993). We were able to update these data with published and unpublished Timber Products Output (TPO) data collected through 1998 (e.g. Brown, 1998; Johnson, 1996; Johnson and Steppleton, 1999; Johnson and Stratton, 1998; Johnson and Brown, 1999). Furthermore, we used national timber supply analyses published in the Renewable Resources Planning Act (RPA) to make future projections of timber harvest levels (Haynes et al., 1995).

Conceptual and computer models were used throughout the study to allow us to describe and generalize about the effects of wood chip mills or other factors on North Carolina's forests, environment and economy. Regional input–output models were used to analyze economic impacts on the North Carolina economy (Aruna and Cubbage, 2000). The Sub-Regional Timber Supply (SRTS) timber supply model (Abt et al., 2000a) was used to analyze timber markets. The SRTS model employs FIA data on forest type and stand age, along with exogenous inputs characterizing demand, growth equations and alterations in land use or silvicultural treatment (e.g. pine plantations) in order to solve for the spatial distribution of harvests among FIA reporting units. There are four such reporting units defined for North Carolina (Fig. 2). In order to validate results for North Carolina, the SRTS model was initially run at three levels of scale: North Carolina as part of a 13 state southeastern region; North Carolina as part of a tri-state area with Virginia and South Carolina and North Carolina in isolation. The model results were found to be robust across the three scales. Thereafter, SRTS models were run for North Carolina at the state level (Abt et al., 2000b).

So that potential effects on wildlife could be linked directly to economic driving forces, we linked existing wildlife-habitat models for birds (Hamel, 1992), reptiles and amphibians (Wilson, 1995) of conservation concern to the SRTS model (Fig. 3; Hess et al., 2000). We used *Partners in Flight* data to develop lists of breeding bird species of concern for each forest management type. *Partners in Flight* is a coalition of federal, state and local government agencies, philanthropic foundations and industry formed in 1990 in response to concerns about declining migrant land bird popu-

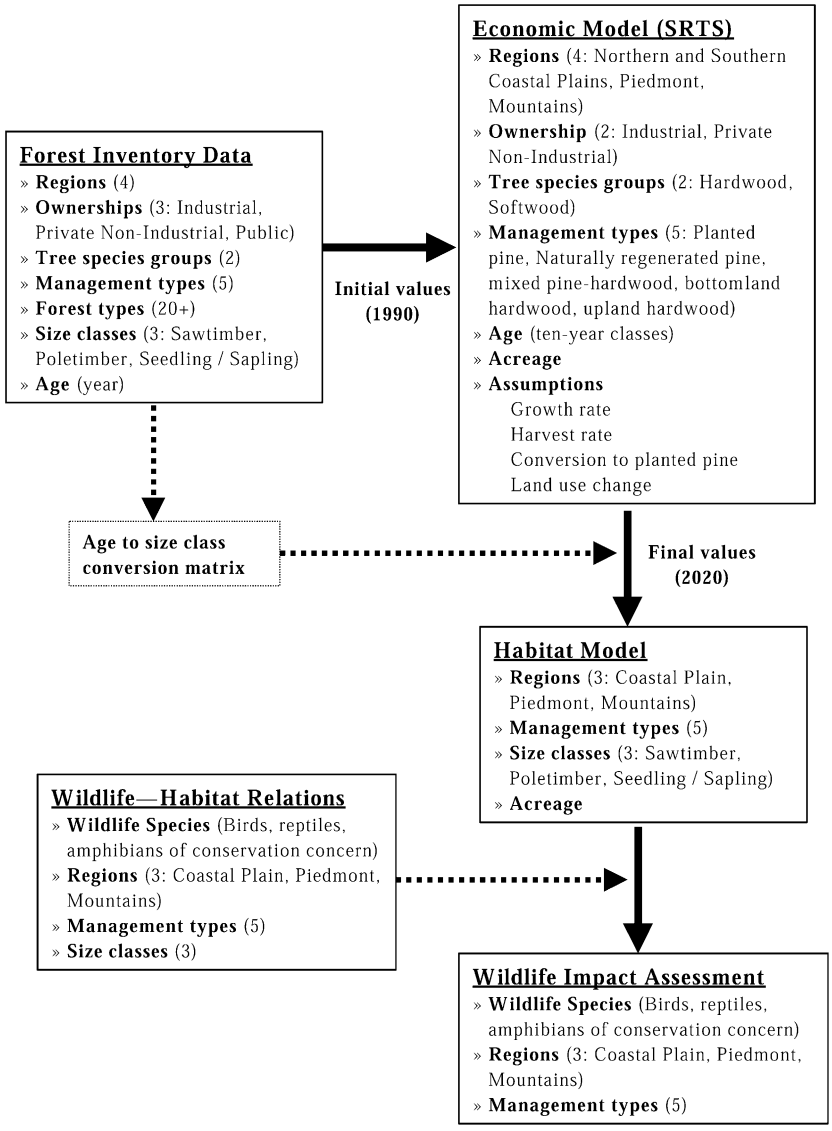

Fig. 3. An economic model (SRTS) was used to drive changes in forest composition and size class distribution. The number of classes in each category is shown in parentheses. Class names are given for each category in the economic model box; they are also provided in other boxes where classes differ from those in the economic model. Changes in the availability of habitat in a combination used by species were assumed to effect populations of the species. Solid lines indicate data flow; dashed lines indicate the use of supplemental information to convert and interpret data.

lations (Beissinger et al., 2000; Carter et al., 2000; available from: http://www.partnersinflight.org). We excluded species that are highly localized in their distribution, highly specialized, or so rare that they cannot be tracked reliably. Because there are relatively few studies of the effects of forest harvest on herpetofauna, we identified forest reptile and amphibian species of concern through consultations with herpetologists at the NC State Museum of Natural Sciences.

Using output from the SRTS model, we projected changes in the size class distribution of the five broad forest management types (naturally regenerated pine, planted pine, mixed pine-hardwood, upland hardwood and bottomland hardwood) within three regions of North Carolina (Coastal Plain, Piedmont and Mountains). Within each region, we used data from the 1990 FIA to convert 10-year age classes to three size classes for each management type: seedling/sapling, pole-timber and sawtimber. These size classes were selected because they correspond closely to those presented in the wildlife-habitat models. Changes in the availability of habitat in a combination used by a species were assumed to effect populations of that species (Hess et al., 2000).

Field data included trips to chip mill locations and to harvested sites across the state. Observations were conducted to gain familiarity with chip mill operations and to assess the economic, ecological and operational implications of chip mill technology (Cubbage et al., 2000b). Additional on-site economic analysis included a qualitative assessment of the species mix and timber grades being supplied to the chip mills as material inputs (Schaberg et al., 2000). Social science field data were collected on community impacts, using an extensive interview process in selected communities across the state, and state-wide data on public preferences for the study and perceptions of chip mills were collected as expressed at four public forums held over the course of the study (Warren, 2000).

Ecological research conducted at the mill sites included assessment of facility location on the landscape, observation of drainage and water quality implications and an analysis of storm water and process water management practices at participating sites (Greco and Gregory, 2000). Further ecological analysis was performed at a few harvest sites throughout the state. This included observation of harvest practices on sites with a chip mill component, and an analysis of post-harvest conditions, including volumes of residual woody debris remaining on the harvested sites, both with and without wood chip harvest components (Hess and Zimmerman, 2000).

3. Results

3.1. Forest resources and wood chip mill assessment

According to USDA Forest Service FIA data (Brown, 1993; Burleson et al., 2000; Cubbage et al., 2000a), forest areas in North Carolina increased from 1938 to 1964, and have declined slightly since then. In 1990, FIA reported 19.2 million acres of forest land in the state, compared to 20.4 million acres in 1964 and 18.1 million acres in 1938. Nonindustrial private forest (NIPF) owners held 76% of the state's timber land area, industrial forest owners held 13% and public owners held 11% (Table 2).

The most recent USDA Natural Resources Inventory (NRI 2000) reported that large private forest land losses occurred in North Carolina from 1982 to 1997, totaling slightly more than one million acres. Urban land area increased almost 1.0 million acres from 1987 to 1997, or 98 000 acres per year. In comparison, according to the 1990 FIA survey data and study projections based on the Forest Service TPO data, timber harvests in North Carolina were estimated to cover approximately 500 000 acres per year by 2000, with 350 000 of those acres being clearcut, and a volume equivalent to approximately 40 000 acres being harvested to furnish wood chip mills (Dodrill and Cubbage, 2000).

An analysis of timber markets in North Carolina found that these markets were cointegrated, across regions and products (Aruna et al., 2000). This finding and numerous discussions with industry experts over the course of the study called into question the appropriateness of considering wood chip mills in isolation from other trends and technologies in the timber products industry.

All trees used in the production of pulp and paper are ultimately chipped into small flakes. Traditionally, this occurred at the pulp mill, and most of North Carolina's pulp mills still chip some portion of the trees they process for pulpwood on site. Technological innovations and increased harvest mechanization now allow timber to be handled as 'longwood' (>20-foot sections). These longwood sections can be transported relatively short

Table 2
Trends in selected forest land and timber statistics in North Carolina, 1938–1990

Characteristic/year	1938	1955	1964	1974	1984	1990
Land areas (*thousand acres*)						
All land	31 004	31 268	31 134	31 055	30 983	31 060
Total forest land	18 102	20 080	20 397	20 025	19 291	19 278
Timber land	17 904	19 345	19 976	19 545	18 788	18 710
Reserved forest land	na	341	372	434	460	524
Nonforest land	12 605	1192	10 738	11 030	11 692	11 783
Timber land ownership (*thousand acres*)						
All ownerships		19 341	20 027	19 545	18 450	18 710
National forest		1047	1056	1011	1117	1082
Other federal		284	314	336	393	490
State and county		289	373	398	412	430
Farmer		13 269	9316	8452	5510	5042
Forest industry		(w/other private)	2503	2135	2510	2420
Other private		4454	6466	7212	8518	9245
Volume of growing stock (*million cubic feet*)						
Softwood	7405	7493	8013	11 305	12 041	12 530
Hardwood	7337	9773	10 451	17 002	19 345	20 212
All species	14 742	17 266	18 464	28 307	31 386	32 742
Timber removals and growth (*million cubic feet*)						
Softwood						
Growth	446	459	430	536	501	590
Removals	396	369	371	437	431	512
Hardwood						
Growth	277	441	383	589	627	570
Removals	174	159	290	314	315	428
All species						
Growth	724	890	812	1124	1128	1160
Removals	570	528	661	751	746	940
Timber land area by broad class (*thousand acres*)						
Species group						
Pine/oak-pine	11 500	9800	10 300	9500	8700	8900
Hardwood	6500	9400	9300	10 000	9800	9800
Management type (year)	1952	1962	1970	1977	1985	1990
Pine plantation	96	359	762	1120	1614	2066
Natural pine	8607	7962	7084	5645	4718	4124
Oak-pine	2027	2405	2468	2433	2264	2295
Uplands hardwood	5653	6248	7010	7545	7059	6838
Lowlands hardwood	3199	3015	2806	2693	2703	2674

Sources: USDA Forest Service, Southeastern Forest Experiment Station, Forest Inventory and Analysis Data; and USDA Forest Service 1988—the South's Fourth Forest, taken from Burleson et al. (2000).

distances to free-standing chip mills for processing. In turn, this reduces overall fiber transportation costs to the pulp mill and frees timber inventory space at the pulp mill for capacity expansion. Wood chip mills have become widely adopted because they improve efficiency, procure wood in areas farther from the mill, enhance wood utilization from existing harvests and reduce costs. The number of wood chip mills in North Carolina increased from 2 in 1980 to 18 in 2000 (Fig. 2). Capacity at the various facilities ranges from as little as 25 000 tons per year to as much as 400 000

Table 3
North Carolina TPO volumes by FIA reporting region 1992–1997 (000 cubic feet)

	1992	1994	1995	1997
Combined softwood TPO				
Southern coastal plain	186 326	201 901	205 117	214 027
Northern coastal plain	180 602	175 496	189 652	170 191
Piedmont	126 753	127 286	131 564	144 495
Mountains	32 472	34 148	28 576	28 576
Total	526 153	538 831	554 909	557 289
Softwood roundwood pulpwood				
Southern coastal plain	79 448	81 834	80 792	84 594
Northern coastal plain	82 936	59 927	66 401	67 381
Piedmont	35 761	40 524	38 364	43 622
Mountains	17 182	16 194	8 015	8 015
Total	215 327	198 479	193 572	203 612
Combined hardwood TPO				
Southern coastal plain	68 324	74 611	67 090	74 556
Northern coastal plain	78 059	86 391	79 737	72 464
Piedmont	81 855	93 400	87 091	116 847
Mountains	44 812	53 122	44 014	44 014
Total	273 050	307 524	277 932	307 881
Hardwood roundwood pulpwood				
Southern coastal plain	41 305	47 288	41 928	47 014
Northern coastal plain	46 205	54 074	48 773	43 196
Piedmont	27 824	34 984	33 736	52 075
Mountains	18 166	23 928	13 862	13 862
Total	133 500	160 274	138 299	156 147

tons per year. Large chip mills, with annual capacity of 400 000 tons, can be expected to process between 300 and 350 truckloads per week, or close to one truck every 10 min throughout a 10-h day at the receiving platform. Chip mills have been used principally in the processing of hardwood pulpwood. In 1997, 15 responding chip mills in North Carolina reported that 78% of their combined process throughput by volume was made up of hardwoods (Schaberg et al., 2000).

According to the Forest Service TPO data for North Carolina, wood chip mills processed approximately 27% of the state's pulpwood harvest and 12% of the state's total timber harvest. Wood chip mills processed approximately 15% of the pulpwood in the Coastal Plain forest survey units, 49% in the Piedmont unit and 75% in the Mountains. North Carolina exported approximately 30% of its total pulpwood harvest, with 25% to other states in the South and 5% to world markets. We found that the increase in the number of wood chip mills was statistically correlated with an increase in timber harvests in the state, especially in the Piedmont and Mountains. Pulpwood is an important component of North Carolina timber production, and Table 3 displays quantities produced and the distribution of harvests among the state's four FIA reporting regions for selected years during the 1990s. Pulpwood accounted for 36% of North Carolina's 1997 softwood production and 51% of its hardwood TPO. Hardwood pulpwood harvests showed a 17% increase during the period, while

softwoods actually declined. As shown, the majority of the timber harvest occurs in the eastern portion of the state.

On the basis of typical timber harvest volumes and the FIA inventories in the state, wood chip mills were estimated to require approximately 1000–1700 acres per 100 000 tons per year of capacity to provide the wood furnish for each mill, depending on the product mix and stand volumes harvested. This would amount to approximately 4000–6700 acres per year for a 400 000 ton mill each year, assuming all harvests were clearcut. The study examined the effects of chip mills on harvests within a 50-mile radius of the mill. Wood chip mills alone would not cause harvest removals to exceed net annual growth within a 50-mile radius around the mills. Generally, all the 18 wood chip mills were located in areas where wood supply was plentiful. However, in the area around four mills, annual hardwood removals already exceeded growth as of 1990, and the wood chip mills built since then would exacerbate this situation.

Timber supply projections using the SRTS model were made for private forest lands. We developed several scenarios and conducted a sensitivity analysis on selected exogenous variables. In addition to initial harvest assumptions (1990–1997) that were estimated as part of the TPO analysis (Schaberg et al., 2000) and assumptions about timber demand, the model was most sensitive to assumptions about the extent of pine plantation establishment, the rate of softwood growth on these more intensively managed plantations and changes to overall forest extent resulting from land use change. In this article, we report a baseline scenario that assumes that pine plantation establishment will continue at a rate consistent with regional averages and that annual growth rates will increase by 40% on industrial land and 20% on NIPF lands by 2020. When coupled with projections of forest land decline based on the 1992 NRI data, and averaging 0.35% decline per year in private forest area, the projections indicated that softwood removals on private forest lands already exceeded growth as of 1990, and would continue to do so through 2020. Thus, total softwood inventory in North Carolina was projected to decrease from 11.2 billion cubic feet in 1990 to 10.3 billion cubic feet in 2020 (Fig. 4). Hardwood removals would exceed growth by about 2005, leading to a slight drop from 17.5 billion cubic feet of inventory in 1990 to 17.3 billion cubic feet in 2020 (Fig. 5).

3.2. Ecological impact analysis

The FIA data show an increase in planted pine forest type in North Carolina of almost one million acres between 1977 and 1990 (Burleson et al., 2000). Under this study projection, planted pine is anticipated to increase by another million acres to a total of 3.1 million acres by 2020. Over the same period, natural pine management types were projected to decrease by approximately 1.1 million acres. Other natural forest management types also showed projected declines from 1990 to 2020, ranging from approximately 225 000 (lowland hardwoods) to 550 000 acres (upland hardwoods and mixed-pine hardwoods). These losses occur from a combination of factors including conversion to nonforest use (principally urban development) and conversion to planted pine management type.

3.2.1. Wildlife habitat

Approximately 200 breeding bird species, 80 reptile species and 90 amphibian species are known to occur in North Carolina. Projected timber harvest increases would most greatly alter forest structures on private forest lands in the Coastal Plain and Piedmont, generally creating less habitat for bird, amphibian and reptile species identified as being of conservation concern in the state. In the Mountains, the habitat for most species of conservation concern would actually increase during the projection period. Current trends in management of public lands to favor mature forests would result in a larger number of acres in larger diameter class timber (Table 4). This would tend to stabilize the generally adverse private land wildlife habitat impacts in the Piedmont, and further improve forest conditions for most species in the Mountains. The component of the wildlife study that focused on coarse woody debris found that harvests including a wood chip mill component did remove a greater amount of material from

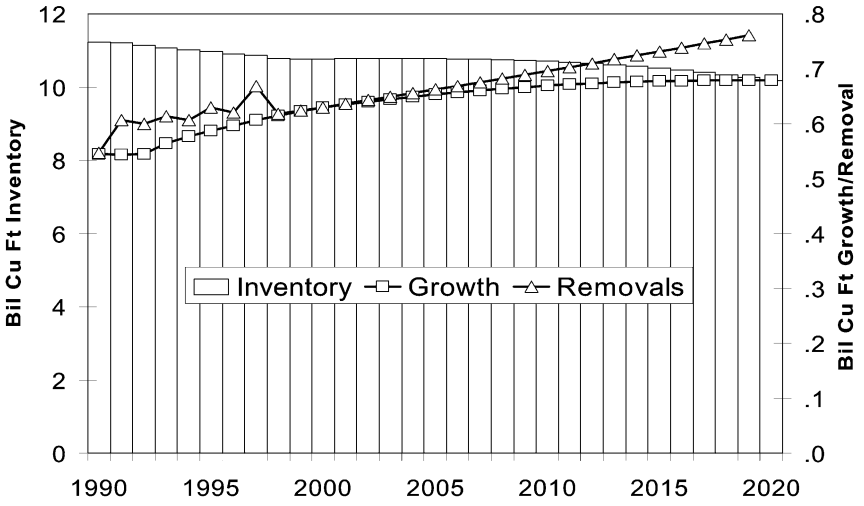

Fig. 4. Baseline scenario of North Carolina softwood inventory 1990–2020.

the sites than conventional harvests, although the wildlife impacts of this are not yet well known (Hess and Zimmerman, 2000).

For the state of North Carolina in aggregate, agricultural lands were estimated to contribute approximately 54.3% of the total erosion load in the state as of 1997; urban land was estimated to contribute approximately 25.2%; minor land uses and rural transportation approximately 11.4% and forest land uses approximately 9.3% (2.6% from federal lands and 6.7% from privately owned forest lands).

Landscape disturbances of various types contributed significantly to total erosion. Disturbance accompanying new urban area development contributed 13.4% of the state's total annual erosion load. Newly established rural roads contributed an additional 0.8% annually. Of the erosion load from

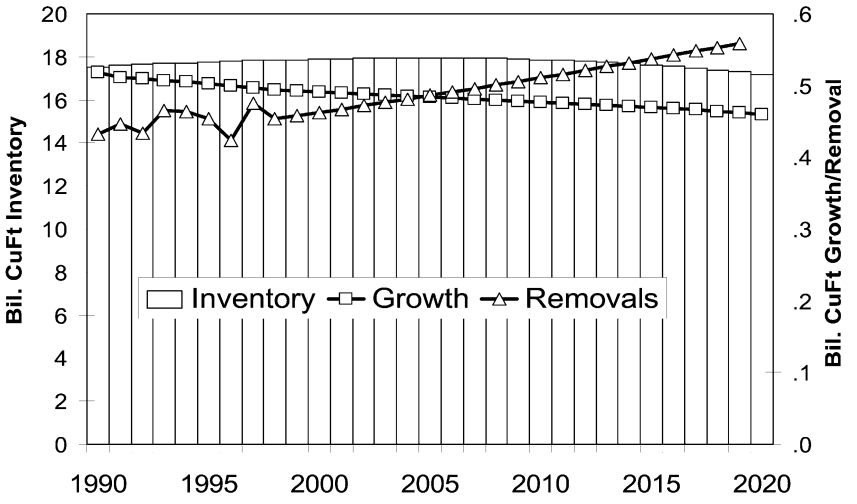

Fig. 5. Baseline scenario of North Carolina hardwood inventory 1990–2020.

Table 4
Summary of potential impacts on bird, reptile and amphibian species of conservation concern, 1990–2020

	Coastal plain		Piedmont		Mountains	
	Private	Overall	Private	Overall	Private	Overall
Birds						
Species considered[a]	97		93		114	
Species evaluated[b]	39		36		43	
Positive impact	11	11	11	22	19	19
Negative impact	26	26	24	13	8	8
Unknown impact	2	2	1	1	16	16
Reptiles						
Species evaluated	19		11		4	
Positive impact	1	1	2	7	2	3
Negative impact	9	9	8	3	2	1
Unknown impact	9	9	1	1	0	0
Amphibians						
Species evaluated[c]	22		21		46	
Positive impact	0	0	3	3	46[d]	46[d]
Negative impact	16[d]	16[d]	16[d]	16[d]	0	0
Unknown impact	6	6	2	2	0	0

The number of species evaluated for each region is shown for private land and combined private and public lands, along with the number of species for which projected habitat changes would have a positive, negative or unknown impact. 'Positive impact' means that habitat for the species is projected to increase during the projection period; 'negative impact' means that habitat is projected to decline; 'unknown impact' means we were unable to assess the direction of change.

[a] We considered breeding species that could be impacted by changes in forest composition and size class distribution. We did not consider waterbirds (e.g. terns, gulls, herons), ocean birds or birds that flourish in urban and suburban areas.

[b] We did not evaluate species that are extremely rare, distributed patchily or restricted in ranges of elevations, because our data were too coarse to assess changes in their habitat.

[c] All 47 species and subspecies of Plethodontidae (lungless salamanders) were examined; 14 occur in the Coastal Plain, 16 in the Piedmont and 41 in the Mountains.

[d] Includes all Plethodontid species that occur in the region.

private forests, all timber harvest practices contributed approximately 1% to the state's erosion total, and disturbance associated with mechanical site preparation for reforestation contributed another 1.2%. The total erosion contributed by undisturbed private forests in North Carolina was estimated to be 4.5% of the state total.

On-site visual inspections of the wood chip mills found that they had effective storm water management plans and did not show visible signs of mill storm water or other effluents adversely affecting off-site water quality. Accelerated channel erosion was the most common storm water problem at wood chip mills (Greco and Gregory, 2000). This could be reduced by using Best Management Practices (BMPs) including detention ponds, water bars, grass filter strips, terracing, rip-rap and similar practices.

3.3. Economic and social impacts analysis

As of 1996, forest product firms employed 105 000 people and the nature-based tourism industry employed approximately 91 000 people. Total employee compensation in the wood-based industries was $3.2 billion; for tourism it was $1.4 billion. The average wood-based industry annual wage was $30 800. The average tourism sector annual wage was $15 500. Industrial output was $13.5 billion for the forest products industry in 1996, and $3.9 billion for the tourism sector. From 1977 to 1996, the wood-based industries grew more slowly than the rest of the state's economy; the nature-based tourism sector grew more rapidly. Regional economic multipliers for the wood-based sector were slightly larger than those for the nature-based tourism sector (Table 5). Nonmarket

Table 5
Summary of IMPLAN regional economic analyses of forest products based and nature tourism based sectors in North Carolina, 1977 and 1996

Sector	Employment			Employee compensation			Industrial output			Value added			Average wage		
	1977 (number)	1996 (number)	Change (%)	1977 (million $)	1996 (million $)	Change (%)	1977 (million $)	1996 (million $)	Change (%)	1977 (million $)	1996 (million $)	Change (%)	1977 ($)	1996 ($)	Change (%)
Lumber and wood products	32 895	39 713	21	280	1023	265	1352	4475	231	456	1661	264	8526	25 770	202
Wood furniture	38 921	42 534	9	390	1131	190	1148	3506	205	469	1428	204	10 014	26 595	166
Paper and allied products	21 189	23 109	9	356	1091	207	1524	5568	265	530	1828	245	16 785	47 224	181
Total wood based manufacturing	93 005	105 356	13	1026	3246	216	4024	13 549	237	1455	4917	238	11 030	30 809	179
Total tourism based sector	32 645	90 974	179	264	1413	435	737	3902	429	420	2206	425	8087	15 532	92
Region's all sectors	2 338 876	4 449 948	90	26 013	117 932	353	82 256	375 694	357	42 252	204 967	385	11 122	26 502	138
% wood-based manufacturing of North Carolina's economy	3.98	2.37		3.94	2.75		4.89	3.61		3.44	2.40				
% Tourism based sector of North Carolina's economy	1.40	2.04		1.01	1.20		0.90	1.04		0.99	1.08				
Economic multipliers, 1996	Type I	Type II		Type I	Type II		Type I	Type II		Type I	Type II				
Lumber and wood products	1.50	2.01		1.65	2.13		1.55	1.88		1.70	2.25				
Wood furniture	1.36	1.80		1.40	1.81		1.43	1.89		1.53	2.10				
Paper and allied products	2.11	3.12		1.87	2.41		1.63	1.93		1.90	2.44				
Tourism	1.29	1.61		1.11	1.43		1.40	1.75		1.42	1.90				

value estimates could equal or exceed the estimates of direct market values from forest products or tourism market returns.

Economic analyses indicated that wood chip mills contributed to greater integration among timber markets in the state. Improved timber markets were estimated to provide up to $5 million or more per year in added returns received by NIPF landowners due to increased pulpwood harvests, better prices or reduced site preparation costs for pine regeneration. Increased stumpage prices from wood chip timber, however, would not make any significant impacts on increased returns to hardwood timber management, nor were they likely to prompt premature harvests of good quality hardwood stands (Snider and Cubbage, 2000).

Social impact analysis found that polarization is increasing particularly because of the growing perception that private property provides public benefits, resulting in conflict and confusion related to private property rights and responsibilities. Differences of opinion and perception are exacerbated by economic and social stress in North Carolina's rural communities (Warren, 2000).

4. Policy and science applications

As described in our methods section, the integrated, interactive method we employed proved to be a useful approach for examining the contentious issue of wood chip mills in North Carolina. Before the study was fairly underway, it had already been characterized in several environmentally focused newspapers as biased and incapable of credible results. Initial reaction by the timber industry was muted, but perhaps not much more enthusiastic. The involvement of the NRLI was probably essential to the study's success, and facilitated structured opportunities for public input. Public input into the study shaped what research questions were examined, and helped change the focus and utility of the research as it proceeded. The study was characterized by an unusual degree of transparency. Research protocols and even the most preliminary or tentative conclusions were available to stakeholder advisory members upon request, and through these representatives also available to their constituents in the general public. The involvement of the stakeholder advisory board from the study's inception resulted in an improved understanding among public constituencies of the study's objectives and constraints. It additionally helped to clarify the goodwill and objectivity of the research team, and led to increased credibility for study processes and results among some stakeholders who were initially suspicious of the study and its motives. Concerns among stakeholders over the potential implications of preliminary study findings often led to probing questioning of both methodology and conclusions at the various study meetings. These questions and comments were at times disconcerting, but without doubt they enhanced the rigor of the study, and probably contributed to improved public acceptance of the ultimate research conclusions.

A content analysis was performed of the numerous public comments of the draft report. This led to some significant changes in the final report content, including (1) detailed tables of land use change based on the NRI data; (2) development of a new land area base for timber supply projections; (3) clearer numerical summaries of wildlife impacts by forest survey unit and (4) detailed tables of soil loss and erosion by land use class for the state. This very open and interactive approach to research problem identification, research methods employed, preliminary results and final reports led to reasonably broad acceptance of the wood chip mill report and its findings by the interest groups involved.

Findings from the wood chip mill report have been used selectively as a reference to support many advocacy positions. The North Carolina Forestry Association has cited the wood chip mill study as confirming the health of North Carolina's forests, and has used the study to assert that no further regulation of forestry is needed in the state. Environmental groups have cited findings that wood chip mills have a demonstrable impact on increased timber harvest levels, as well as adverse impacts on sustainable timber inventories and many wildlife populations in the Coastal Plain and Piedmont. On the basis of selected study findings, environmental groups have advocated requirements for notification before timber harvests may occur, mandatory BMPs, mandatory logger certification

and a moratorium on the construction of new wood chip mills.

The North Carolina Department of the Environment and Natural Resources made many policy recommendations to the legislature for consideration, generally requesting stricter environmental controls of forest practices and suggestions for enhanced forest development program incentives. At present, few new initiatives are being developed by the North Carolina legislature owing to budget shortfalls. However, the issues examined in the Wood Chip Mill Study are enduring, and are expected to re-emerge for consideration as the state economy rebounds, and as public and interest group pressure for stricter forest practice controls increases.

5. Discussion

The North Carolina wood chip mill study served in some ways as a lightning rod for the highly polarizing issue of forest resource management within the state. The study team set as its principal objectives the goals of providing objectivity and the best available science to inform what was clearly to be a heated debate over the future of chip mills in North Carolina. In the process, we sought to keep the research process timely, transparent and flexible to meet the needs of the evolving study. We sought to delineate for policy makers and for stakeholders with often conflicting views what was known with certainty about chip mill impacts, and where the state of the science was more conjectural.

One early and important result of the study was the identification of chip mills as a processing technology, and not an independent cause of timber harvest. The study did conclude that chip mills are correlated with increased harvests, particularly of hardwood pulpwood and in the western portion of the state. We quantified the amount of additional harvest processed by each incremental mill. Chip mills do create more efficient markets and improve economic incentives to both sellers of hardwood pulpwood and pulpwood purchasers at pulp mills, but these economic welfare benefits occur in the context of overall market demand for lower grade timber products. The root cause of the increased pulpwood harvests that occurred throughout the Southeast in the 1990s is more likely to reside in the increased domestic and especially the international demand for US pulp and paper that occurred during that time. Similarly, an abatement in that demand curtails throughput at chip mills as shown in recent years, and will make more low grade fiber available for competing uses such as oriented strand board and pallets.

The direct environmental consequences of chip mills on water quality were found to be minimal. Off-site impacts on water quality were found to be modest relative to other influences such as agriculture or urban storm water and to be mostly transitory in nature, returning to baseline within a few years (Richter, 2000). The aquatic component of the study raised questions about cumulative effects of expanded forest harvests on the forest–riparian interface and on the vitality of sensitive aquatic systems, and the wildlife component of the study identified the elevated removal of biomass from chip mill harvest sites and the tendency to replant these sites in planted pine forest as two elements with possible adverse effects. These issues could be significant, as the harvest areas in question can be extensive. For each seral stage of forest habitat, the total area affected in each class would be the annual harvest acreage processed by a chip mill, multiplied by the number of years the regenerating forest remains in that age class (e.g. a 4000 acre annual chip mill harvest creates 40 000 acres in the 0–10 age class). However, at this point, such concerns are conjectural, as there are not presently sufficient data for rigorous conclusions about impacts.

There was substantial difference in regional public response to the study, and this was sometimes at variance with intuitive conclusions that might be drawn from the study's scientific findings. The public was much more polarized over the land use rights of NIPF forest owners and over the impact of chip mills in the western portion of the state. Public forums in this portion of the state were well attended and often contentious, centering around concerns over amenity values, property rights, community safety and quality of life, and the sustainability of the hardwood forest resource. Findings from the study indicate that overall har-

vest levels in the western portion of the state have been comparatively modest and that hardwoods are much more intensively harvested in the eastern Piedmont. The greatest inventory and acreage declines were found among natural pine forests, occurring principally in the Coastal and eastern Piedmont portions of the state. This was also the portion of the state that experienced the great majority of the state's overall timber harvest. However, public concerns over chip mills were not found to be a significant issue among more eastern residents of the state in our study sample.

The forest resource component of the study evolved from its initial consideration of chip mills to a more generalized assessment of forest harvest levels and timber sustainability within the state. In this context, the findings of the study are significantly affected by assumptions about the extent and productivity of pine plantations. More conservative plantation estimates would directly exacerbate the softwood inventory decline noted for North Carolina, and could indirectly hasten the decline of hardwood inventory through substitution of hardwood fiber for the less abundant softwoods. Similarly, the study used a fairly conservative estimate of 40% as a factor for pine productivity increase on industrial plantations by 2020, and 20% increases for NIPF growers. Much more aggressive assumptions are not uncommon in the literature (Siry et al., 2001) and adoption of these more aggressive growth rates could ameliorate or reverse the projected declines of softwood inventory within the state.

6. Conclusions and future research needs

This study was undertaken as an integrated ecological and economic study. In the process of conducting the study and seeking to integrate these disciplinary approaches, several compelling research opportunities emerged. Our economic models are generally robust at fairly large levels of scale, and are constrained by sampling costs associated with data collection at finer scales. Our ecological models are robust at much smaller scales and are constrained by the high degree of specificity associated with observed communities, and the high levels of variability that can occur across sites. Finding methods to increase ecological generalization and to improve economic specificity will be required if these disciplines are to be successfully integrated to address environmental concerns.

The study found evidence of substantially increased levels of harvest in North Carolina over recent decades, and this is consistent with data reported from other southern states as well. Certainly, the number of chip mills in the southeastern region has increased dramatically since 1980. The study identified several silvicultural issues of note, but for which there are insufficient data for conclusions. Chip mills encourage more complete removal of timber biomass from harvest sites. Effects that may result from the widespread adoption of this more complete biomass removal over large areas throughout the South are not well understood, but represent an important area for study, both in terms of forest nutrient dynamics and residual wildlife habitat in harvest areas. The growing importance and prevalence of intensively managed pine plantations raises questions about nutrient retention within these stands and the potential for downslope nutrient export, as well as numerous ecological questions about their utility for wildlife habitat and as a source of nutrient supply to downslope aquatic systems. These intensively managed pine plantation ecosystems are a relatively recent addition to the southern landscape, but their importance and growing extent argues for a better understanding of their ecological dynamics.

In its policy implications, the North Carolina wood chip mill study has been widely distributed via the SCSF web site, presentations have been made to groups in many states, and the research has been cited widely in policy and scientific meetings and articles, including in congressional testimony. The study continues to be referred to in policy debates both within and beyond North Carolina and will lead to improvements in ecological and economic analyses of forest practices.

Acknowledgments

Research conducted for the North Carolina wood chip mill study was supported by funding

from the North Carolina Department of Environment and Natural Resources and by Region 4 of the Environmental Protection Agency. Much help in kind came from a variety of North Carolina state agencies, and particularly from the North Carolina Division of Forest Resources and the North Carolina Natural Heritage Program, both of which contributed significant data and research assistance to the study.

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