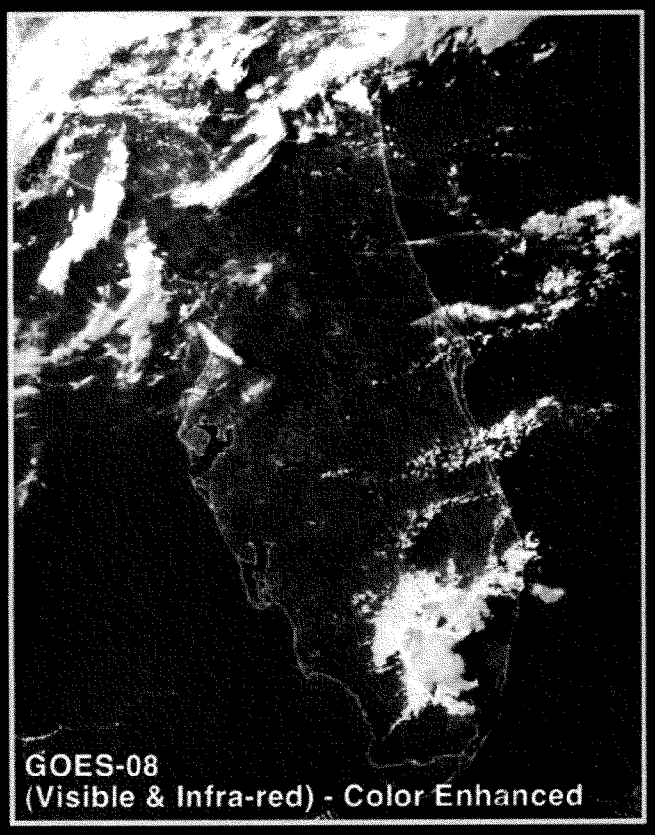
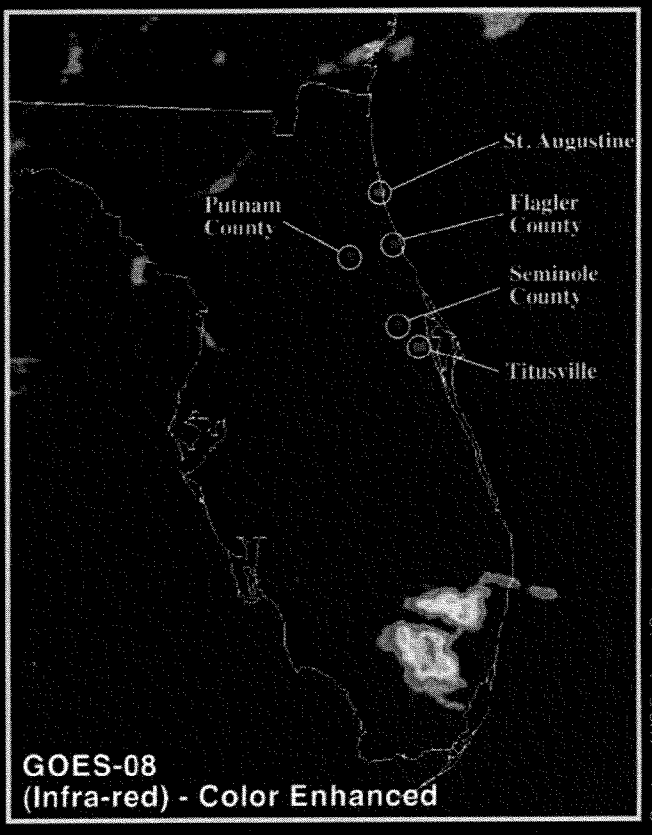
What Is the Price of Catastrophic Wildfire?





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ABSTRACT

We modeled and analyzed the economic impacts of the six weeks of large, catastrophic wildfires in northeastern Florida in June and July 1998, among Florida's most devastating in recent history. The result of the unusually strong El Niño-Southern Oscillation (ENSO) in 1998, the Florida wildfires produced economic impacts of at least $600 million, similar in scale to recent category-2 hurricanes. Improved understanding of the interactions between management, wildfire, and its costs may yield large payoffs to society by identifying optimal intervention activities.

Keywords: economics;fire management; Florida; policy

Wildfires engender far-reaching costs and losses to society. Government agencies and private landowners spend money for presuppression and suppression activities as wildfires damage the physical stocks and productivity of resources, such as timber and capital. However, wildfires also can produce gains, for example, by sustaining fire-dependent forested ecosystems.

The increasing costs and damages associated with wildfires during the 1990s suggest a need to analyze the amount we should spend to prevent and suppress wildfires. Using the least-cost-plus-net-value-change criteria, Gorte and Gorte (1979) explained that the economically optimal amount of presuppression effort or expenditures is the point at which they minimize the wildfire's cost, including both presuppression and suppression costs, plus the net value change of the affected resources (the sum of all wildfire-induced gains and losses).

Clearly, minimizing the economic impacts of catastrophic wildfires re-

Above: Fire plumes in Florida as seen from the NASA GOES-8 satellite, June 6, 1998.

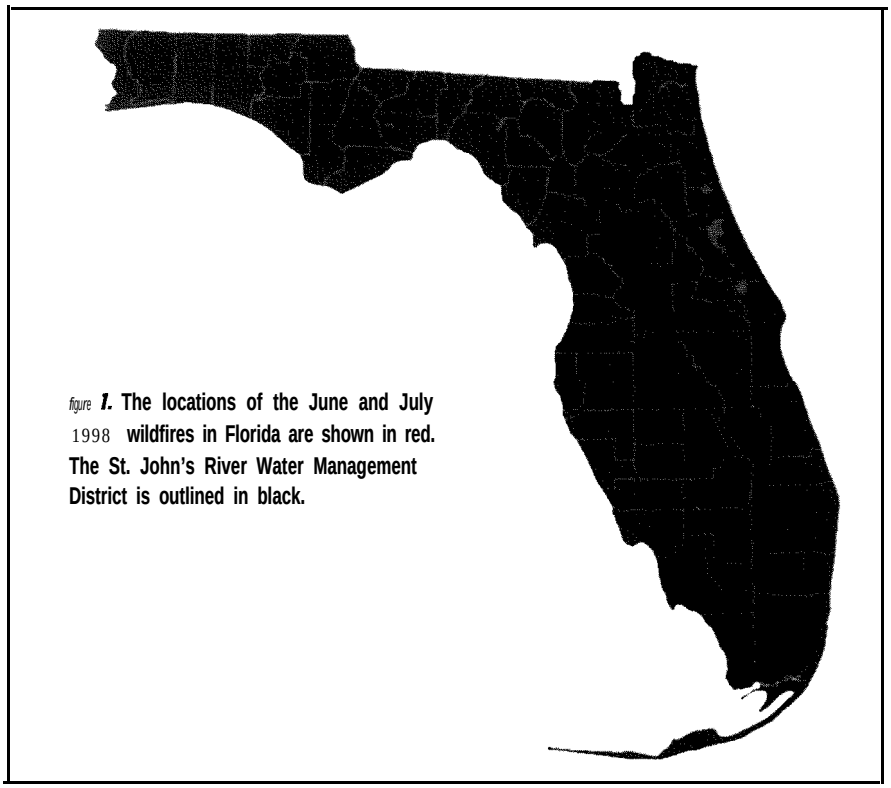


figure 1. The locations of the June and July 1998 wildfires in Florida are shown in red. The St. John's River Water Management District is outlined in black.

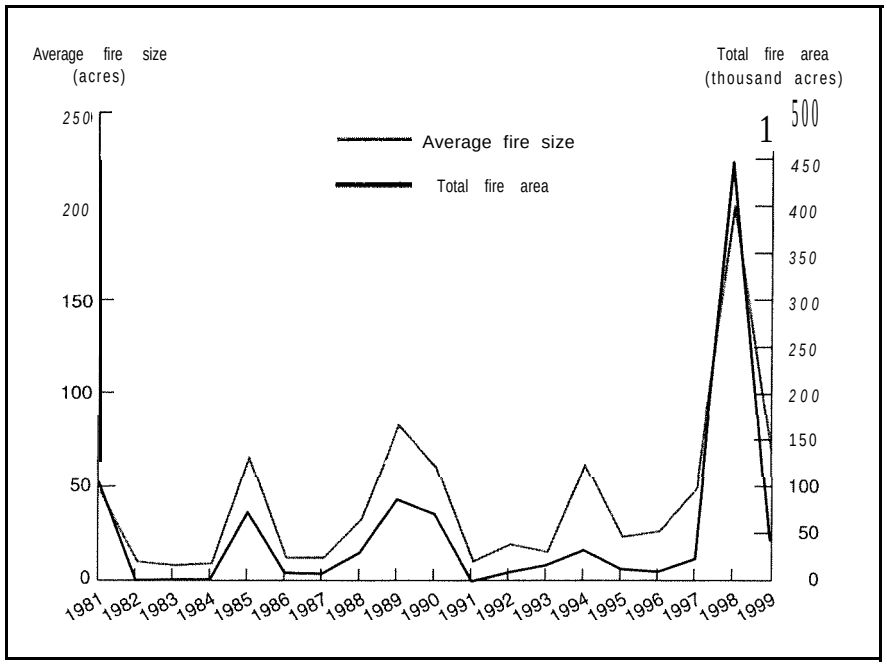


Figure 2. **Average fire size and total fire area for Florida in June and July, all fuel types (federal lands excluded),** 1981-99.

quires careful calculation of all associated costs, losses, and gains. Nevertheless, we know of no organization in the United States that systematically and empirically quantifies economic impacts of wildfires. The National Interagency Fire Center (2000) reported that the federal portion of wildfire suppression expenditures averaged $500 million per year for the period 1994-99. Such totals, however, shed no light on suppression expenditures for one fire or set of fires to enable optimal suppression and prevention policies. Although a few analysts have expanded wildfire cost accounting to include other economic components of costs and net value change (e.g., Bellinger et al. 1983; Mills and Flowers 1985; PricewaterhouseCoopers 1998), in most studies net value change usually refers only to timber losses (Gorte and Gorte 1979).

Wildfires create both short- and long-run economic impacts. Where human populations are high and wildfires are catastrophic, unique near-term losses associated with large-scale local economic disruptions are often generated. Long-term costs and losses are incurred in vegetation management, routine wildfire monitoring, and impacts on timber and other forest values. The summer of 2000, when wildfires burned more than 8 million acres in the United States, is a testament to the potential impact of wildfires on people and their economic systems. As human populations increase, and as the number of structures in and near wildlands increases over time, the costs and economic losses from occasional catastrophic wildfires are likely to increase. Detailed analyses of the potential impacts of catastrophic wildfires are needed to help the public and policymakers better understand the potential return to alternative presuppression and suppression strategies to reduce risks and impacts of wildfires.

Wildfires of 1998

The fire season of 1998 was the most devastating in Florida's recent history. Approximately 500,000 acres burned, mostly in the forests of 18 northeastern Florida counties (fig. I) that compose the St. John's River Water Management District. Although the actual number of fires in Florida (federal lands excluded) for 1998 was below average (4,9 16 fires versus the 5,720 average for the period 1981-99), more than twice the usual number of wildfires occurred in the summer months of June and July 1998 (2,255 versus an average of 935). The 1998 fires also were unusually large, averaging 200 acres in 1998 compared to 59 acres in an average year, propelling total area burned to more than twice the long-term average between 198 1 and 1999 (Jig. 2).

The 1998 catastrophic wildfires

were caused in large part by the weather patterns associated with an unusually strong ("super") El Nifio-Southern Oscillation (ENSO), the central Pacific Ocean temperature fluctuation that affects weather patterns worldwide. ENS0 can be divided into three recognizable phases-El Niiio, La Niña, and neutral (Green et al. 1997)--all of which affect weather in Florida. The El Niño phase is characterized by heavier-than-normal precipitation in Florida, whereas the La Nifia phase usually produces reduced levels of precipitation or drought. The neutral phase, following an El Niiio-La Nifia oscillation, is typified by normal precipitation patterns in Florida.

The ENS0 pattern of 1997-98 (fig. 3) was atypical compared with other ENSOs because of the extraordinarily high rainfall in Florida during the wet El Niño portion of the cycle. The quick return to the La Nifia phase was also atypical and created a severe drought. During the El Nifio phase (1997 and early 1998), vegetation accumulated in northeastern Florida. By April 1998, when the drought took hold, the vegetation dried up and became a large and hazardous fuel source. In late spring and early summer 1998, the Keetch-Bryam drought index, a standard measure of wildfire danger, flirted with the maximum possible value of 800 for several weeks. Indeed, these conditions were so extreme that bald cypress swamps and other lowland forests burned more often than upland types (Mercer et al. 2000).

In addition, the weather patterns present under La Nifia and the resulting fuel buildup changed the mix of ignition sources for wildfire. Typically, arson is the most common source of wildfires in Florida. During the spring and summer of 1998, however, lightning was the most prevalent ignition source, with total strikes exceeding 60,000 for the St. John's River Water Management District from June to mid-July 1998.

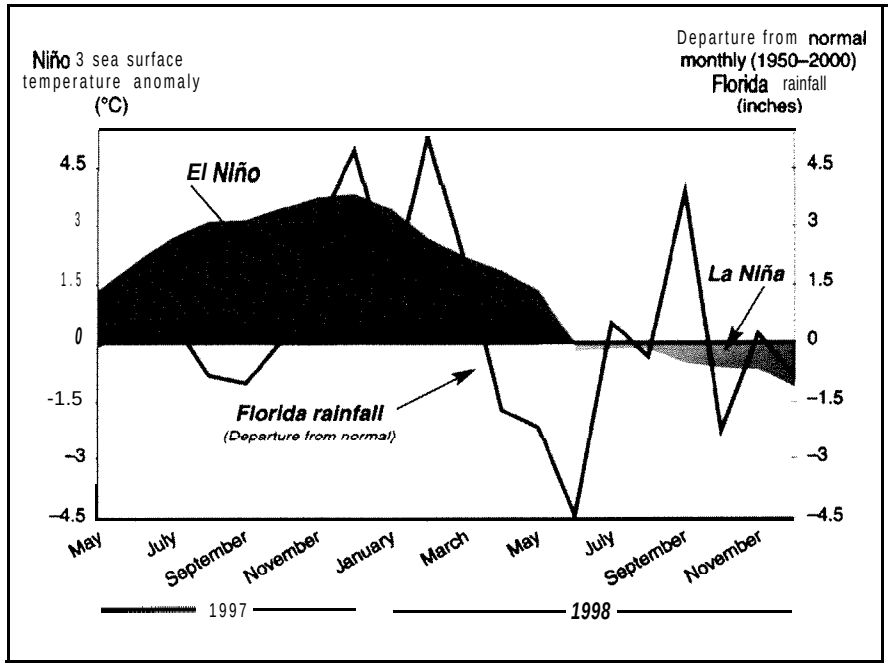


Figure 3. **Nifio 3 sea surface temperature anomaly and departure from normal rainfall for Florida by month from May** 1997 **to December** 1998. **The El Nifio and La Niña phases are depicted in green and orange, respectively.**

Economic Effects

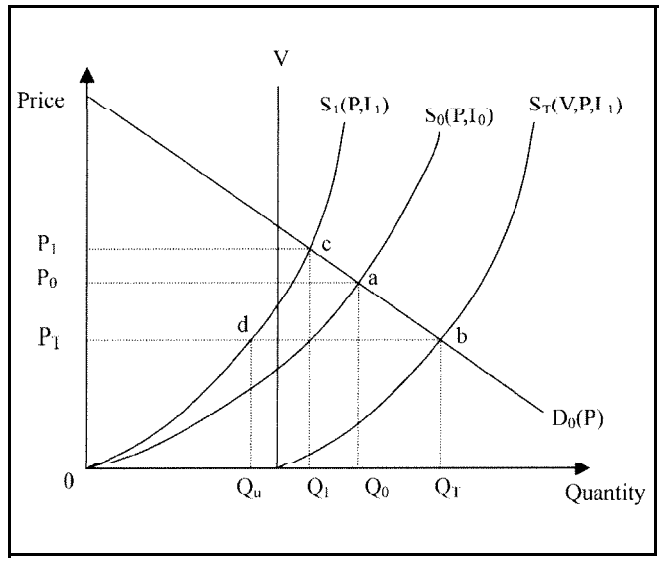
We examine seven major categories of costs and losses associated with catastrophic wildfires: presuppression costs, suppression costs, disaster relief expenditures, timber losses, property damage, tourism-related losses, and human health effects. This list is by no means exhaustive, as other potential costs and losses may exist (e.g., lost wages, decreased quality of life, higher long-run firefighting expenditures, landscape rehabilitation, environmental degradation). But examining these seven categories allows us to focus on data that is readily available to produce a conservative, lower-bound estimate.

Unlike much of the wildfire-vulnerable West, northeastern Florida is heavily populated, and private land ownership predominates. The wildfires of 1998, therefore, required evacuations of hundreds of thousands of people and destroyed private and public timber resources. Because Florida, like the West, is a popular tourist destination, the 1998 wildfires also disrupted tourism to popular attractions such as beaches, Disney World, and a major stock-car race. The smoke from the wildfires also posed a potential health risk to Florida's large and vulnerable elderly population. In the following section, we examine the economic scale of each of these impacts in Florida.

Timber losses. Natural catastrophes such as wildfires can have short- and long-term effects on timber markets. Short-term effects (one to two years) include the immediate destruction of valuable standing timber and economic disequilibrium associated with the flooding of markets with salvaged timber. The glut of salvaged timber drives prices downward temporarily, which affects owners of the killed timber, owners of undamaged timber, and timber consumers. Holmes's 1991 analysis of a major southern pine beetle outbreak in Texas and Louisiana, and Prestemon and Holmes's 2000 study of the effects of Hurricane Hugo in South Carolina document the short-run price drops caused by gluts of salvage material. Long-run effects on timber markets can arise from the loss of a large portion of standing inventory, a loss that tends to drive prices upward for extended periods and produce a windfall for owners of undamaged timber. They also can create conditions favorable for a contraction in timber demand. Prestemon and Holmes (2000) found that the elimination of more than 10 percent of the inventory in a region could drive up long-run prices, assuming no contraction in demand. Therefore, large-scale catastrophes often redistribute wealth among producers and consumers and cause a net economic loss.

Timber Market Effects of the 1998 Wildfires in Florida

We quantified economic effects of the 1998 wildfires in northern Florida's southern pine sawtimber and pulpwood markets (data limitations prohibit analyses of hardwood markets impacts). The affected region corresponded closely to *Timber* Mart-South Area 1 (Norris Foundation 1998), so base price estimates were based on the *Timber Mart-South* report for Area 1 for the second quarter of 1998. We assumed that northern Florida timber prices moved in a way similar to price changes identified by Prestemon and Holmes (2000) for sawtimber and pulpwood stumpage in South Carolina following Hurricane Hugo: a salvage glut period, in which prices were lower than they would have been without the catastrophe, and a price rise after the salvage period was completed. The price rise after Hugo followed the loss of 16 percent of southern pine inventory in the coastal plain and 'lower Piedmont 'of South Carolina. A similar scale of inventory loss was experienced in northern Florida-14 percent of sawtimber inventory and 19 percent of pulpwood inventory (Mercer et al. 2000)--so this price path seems justified. Of the sawtimber and pulpwood inventories killed in Florida in 1998, landowners salvaged approximately 24 percent and 23 percent of killed pine and hardwood volume, respectively. These salvage quantities amounted to more than twice the average annual removals for the region, implying that both pine and hardwood timber markets faced gluts of salvage materials for several months after the fires ended. Communications with experts in the field revealed that the salvage period was over by mid- 1999.



A statistical analysis of the price effects of the Florida wildfires in the manner of Prestemon and Holmes (2000) was not possible, because we lacked a long time series of observed prices following the wildfires. As an alternative, we estimated the timber price changes by applying a structural economic model: using supply-and-demand relationships available in the literature and data from Mercer et al. (2000) on inventory losses and salvage volumes. The price effects were estimated by assuming a path of salvage volume and regular harvest volumes in northern Florida and then finding the pure effects of the salvage glut and inventory reductions caused by the fire on prices. In other words, we calculated how far observed prices in northern Florida should have departed from actual prices in the quarters following the fires. Using those price departure estimates, salvage volumes, and harvest quantities, we calculated the economic surplus (consumer and producer surplus effects) of the fires on the northern Florida economy. This approach was partial equilibrium, ignoring any feedback effects that may occur between the timber sector and other sectors.

Methods

The figure below is a graphical representation of the northern Florida timber market, showing the shift in supply and the glut of salvage of either sawtimber or pulpwood stumpage offered to the market. Before the 1998 wildfires, equilibrium was at point a, the intersection of the supply curve based on the original available inventory, $S_0(P,I_0)$, and demand, D, establishing a price P_0 and a quantity Q_0. During the first salvage period after the fires, a glut of damaged material, V, entered the pulpwood and sawtimber markets. This material was combined with the undamaged timber (Q_U) offered from the new supply curve, $S(P,I_1)$. The new supply of timber was based on a smaller inventory (I_1) and intersected the demand curve at point *b*, establishing a short-run price (P_T) and quantity (Q_T). The salvage volume, V, gradually shifted toward the price axis as the salvage material was exhausted. We assume that four-sevenths of the salvaged volume was recovered in the first period after the fires (the third quarter of 1998), two-sevenths in the fourth quarter of 1998, and one-seventh in the first quarter of 1999. (Although other allocations across quarters could have been used, such as a linear decrease over time, the estimates of economic surplus changes would have been only trivially different from our assumed allocations. The salvage allocations over time also better fit price paths observed during the salvage period for Hurricane Hugo [Prestemon and Holmes 20001.)

After the salvage was exhausted, the new equilibrium, based on the new supply curve, was point *c*, a price of P_1 and a volume per quarter of Q_1.

Supply-and-demand equations were specified as exponential functions, and changes in surplus were based on changes in the areas between the price axis and the curves (Just et al. [1982] provided an overview of this technique for calculating welfare changes.)

Each quarter after the fires, an estimated price change was calculated, based on a salvage wood quality adjustment

of 1.5 (Holmes 1991) and an equilibrium condition that required the total green equivalent volume of timber supplied by producers (undamaged plus quality-adjusted volume of salvaged timber entering the market) to equal the quantity demanded by consumers. The following condition therefore held each period for each product:

$$S_1(P,I_1) + (V/K) = D(P)$$

or (1)

$$a_0 P_t^{a1} I_1^{a2} + (V/K) = b_0 P_t^{b1}$$

where S_1 was undamaged supply after the fires, I_1 was undamaged timber inventory volume after the fires, V was salvage after the fires, K was the salvage quality adjustment, D was demand quantity, and P was the equilibrium price that made (1) hold.

Economic surplus changes were counterfactual, comparing the predicted real price and quantity changes due to the wildfires to a scenario in which no fires occurred in that six-week period of 1998. Economic surplus changes due to the price and quantity changes were divided into two parts: those experienced during the nine-month salvage period (short-run) and those predicted to occur over the ensuing years (long-run). The long-run surplus changes were calculated for every quarter after the salvage period, to time horizons of 20 years for pulpwood and 40 years for sawtimber, reasonable approximations of the time needed for inventories to grow back to prefire levels. Each quarter's surplus changes for both pine sawtimber and pine pulpwood were then discounted to 1998 values using a real discount rate of 6 percent.

Because elasticities used are estimates based on existing research for the South as a whole, instead of the northern Florida area, we performed a sensitivity analysis on the assumed values. The sensitivity analysis was done by multiplying supply and demand elasticities with respect to price times 0.5 and 1.5, but holding constant the real discount rate of 6 percent and the elasticity of supply with respect to inventory.

Data

The USDA Forest Service (Brown 1996) provided timber production data for northern Florida, while elasticities of supply with respect to inventory and elasticities of supply and demand with respect to prices were those used in the Subregional Timber Supply Model (Abt et al. 2000). Timber salvage and inventory loss data were obtained from large industrial producers and the state of Florida. Salvage amounts for nonindustrial private forestland owners were set to zero, and inventory losses for that group were estimated using GIS estimates of the area of timber inventory burned and average standing volume data obtained from the state and the forest industry.

Results and Discussion

Results of our calculations and sensitivity analyses are in the table below. Estimates of total economic surplus changes for the southern pine sawtimber plus pulpwood markets ranged from a net –$323 to –$509 million. These changes were unevenly distributed between producers and consumers, and between owners of damaged timber and owners of undamaged timber. Producers of timber who had no wildfire losses are expected to gain between $400 million and $1.4 billion in the long run, due to persistently higher prices in that part of the state. Producers of timber who experienced wildfire damages gained between $33 and $61 million in salvage revenues, small compensation for the long-run losses they will experience and the loss of unsalvaged timber, amounting to around $400 million. Consumers, although gaining from short-run price discounts and greater volume available during the salvage period, lose in the long run, due to persistently higher prices. These higher prices and lower consumption outweigh the temporary gains, yielding net losses between $400 million and $1.5 billion.

Losses and gains in producer and consumer surplus caused by 1998 wildfires in the St. John's River Water Management District, Florida ($ million 1999), assuming a 6 percent real discount rate.

	Price elasticities		
	0.5	1.0	1.5
Change in producer surplus, undamaged market	1,419	621	395
Change in consumer surplus, entire market	(1,501)	(653)	(414)
Change in producer surplus due to lost inventory	(460)	(407)	(365)
Change in producer surplus from salvage revenues	33	52	61
Total change in consumer and producer surplus	(509)	(387)	(323)

NOTES: *Supply elasticities with respect to inventory were set at 1.0 for both sawtimber and pulpwood markets. Demand elasticities with respect to price for both products were -0.5. Supply elasticities with respect to price for both products were 0.3. These were the same as those used by Abt et al. (2000). Negative surplus changes imp/y net economic losses, and positive changes imp/y net economic gains.*

Table 1. Wildfire impact on summer tourism for counties in the St. John's River Water Management District, Florida, June-August 1998.

County	Change in summer hotel revenue	Change in summer tourist spending	Total change
Alachua	$ (403,181)	$ (510,522)	$ (913,703)
Baker	—	—	—
Brevard	(4,599,488)	(5,823,976)	(10,423,424)
Clay	(35,744)	(45,260)	(81,004)
Duval	1,033,772	1,308,997	2,342,769
Flagler	(442,148)	(559,862)	(1,002,010)
Indian River	(302,288)	(382,768)	(685,056)
Lake	(330,676)	(418,713)	(749,389)
Marion	—		
Nassau	(299,347)	(379,044)	(678,391)
Okeechobee	28,883	36,573	65,456
Orange	(48,835,556)	(61,837,230)	(110,672,786)
Osceola	9,169,125	11,610,256	20,779,381
Polk	(666,846)	(844,384)	(1,511,230)
Putnam	129,424	163,881	293,395
St. John's	(7,823,967)	(9,906,972)	(17,730,939)
Seminole	1,169,430	i,486,771	2,650,201
Volusia	(8,790,112)	(11,130,336)	(19,920,448)
Total	$ (60,998,679)	$ (77,238,589)	$ (138,237,268)

We calculated that the 1998 wildfires produced between $322 and $509 million in net losses to the Florida pine timber market (for details, see "Timber Market Effects of the 1998 Wildfires in Florida," p. 12). These losses exclude the hardwood timber market, where effects are probably smaller but likely amount to tens of millions of dollars. Because of data limitations, we did not estimate the economic effects of the wildfires on hardwood markets, but hardwood timber inventory losses were similar in scale to softwood inventory losses (Mercer et al. 2000). Different segments of society were unequally affected by the wildfires, and these differences were economically significant: Consumers lost $400 million to $1.5 billion, owners of damaged timber lost $360 to $460 million, and owners of undamaged timber gained $400 million to $1.4 billion.

Costs ofpresuppression andprescribed burning. Each year in Florida, approximately 506,000 acres of land are subjected to prescribed fire to reduce the risk of wildfire. Assuming a treatment cost of $25 per acre, prescribed burning in Florida costs federal, state, and private landowners about $12.7 million annually. Before the major wildfires in June, about $9.4 million (covering 377,936 acres) had been spent on prescribed fire in Florida in 1998. Total presuppression and vegetation management expenditures may easily surpass $12.7 million annually, as we do not have data for other management activities aimed at wildfire risk reduction, such as thinning and herbicide treatments.

Costs of suppression and disaster relief: The Federal Emergency Management Agency (FEMA) approved wildfire suppression reimbursement and disaster relief aid to Florida in the wake of the 1998 wildfires. FEMA originally authorized $50 million for the Fire Suppression Assistance Program (FSAP), although the final tally was expected to top $100 million (this discussion draws from Suiter and Copenhaver 1999). FSAP reimbursed state and local governments for 100 percent of their firefighting costs, including wages for firefighting crews and the costs of their gear, and the leasing of multiple fixed-wing aircraft, helicopters, fire engines, and bulldozers. FEMA disaster relief expenditures were expected to total $20 to $25 million, with 25 percent representing state and local government disaster relief expenditures. Disaster relief covered the expenses of debris removal, relief centers, temporary housing, and crisis counseling.

Property losses. The 1998 wildfires damaged or destroyed 340 homes, 33 businesses, and several cars and boats. These losses amounted to between $10 and $12 million (Saunders 1998). Because of data constraints, this estimate only includes losses to insured property. Homes accounted for the majority of the total property losses.

Tourism and trade losses. Compared to previous years, tourism expenditures in northeastern Florida fell considerably below expected levels during the summer months of 1998. While nationwide media coverage of the effects of the 1998 wildfires-including reports on mandatory evacuations, excessive smoke, and road closures-discouraged travel to the state, the unusually hot, dry conditions may also have reduced the attractiveness of Florida to tourists. As we were unable to separate out the independent economic effect, if any, of merely bad weather on tourism, we assumed that all the reductions in tourism were the result of the wildfires.

We statistically tested for changes in tourism during the 1998 wildfire season for the 18 counties lying at least partially within the St. John's River Water Management District. The statistical analysis of hotel revenue effects used data from the Florida Department of Revenue's transient rental (hotel) tax receipts, where revenues equal the hotel tax divided by the corresponding county hotel tax rate (Baker and Marion Counties were excluded because they do not report hotel taxes). The months of June, July, and August 1998 were analyzed, with August included to account for any lagged effects the fires may have had on tourism.

The change in tourism expenditures was estimated by comparing predicted (without fire) with observed expenditures. The predicted level was determined by multiplying 1997 tourism revenues, as recorded by each included county, by 1 plus the mean annual percent change occurring over the previ-

ous lo-year period. Calculations were performed separately for June, July, and August 1998. To determine whether the change in gross sales from 1997 to 1998 was statistically significant, the percent change was compared to the 95 percent confidence interval for the average percentage change occurring in the previous 10 years for each county. If the percent change from 1997-98 fell outside the confidence interval, it was determined to be statistically significant.

The difference in tourism expenditures in June and July 1998 compared to the previous 10 years was not statistically significant. August tourism losses (79,219 1 hotel-room nights), however, were statistically significant compared to the predicted revenues for August 1998 ($p < 0.05$). Reduced tourism resulted in an estimated $61 million gross loss in hotel revenues and an estimated $77.2 million gross loss in non-hotel-related tourist spending. Most of these losses were experienced by the hotels and businesses of Orange, Volusia, St. Johns, and Brevard Counties

Table 2. Wildfire emissions by county for the St. John's River Water Management District, Florida, June-July 1998.

County	Acres burned[1]	Particulates	Carbon monoxide	Volatile organics[2]	Nitrogen oxide
			tons		
Alachua	6,784	519	4,274	733	122
Baker	665	51	419	72	12
Brevard	57,042	4,364	35,937	6,161	1,027
Clay	6,962	533	4,386	752	125
Duval	8,438	646	5,316	911	152
Flagler	95,809	7,329	60,360	10,347	1,725
Indian River	30	2	19	3	1
Lake	882	67	556	95	16
Marion	973	74	613	105	18
Nassau	2,219	170	1,398	240	40
Okeechobee	1,274	97	803	138	23
Orange	6,704	513	4,223	724	121
Osceola	8,201	627	5,166	a86	148
Polk	7,094	543	4,469	766	128
Putnam	4,532	347	2,855	489	82
St. John's	11,849	906	7,465	1,280	213
Seminole	2,046	157	1,289	221	37
Volusia	161,329	12,342	101,637	17,423	2,904
Total	382,833	29,287	241,185	41,346	6,894

[1] Grassy fuels excluded.
[2] Expressed as methane.

Health care costs. Air pollution emissions were estimated for the 1998 summer wildfires by county ***(table 2)***, and these emissions formed the basis for estimating some of the economic effects of the wildfires on health. Brevard, Flagler, and Volusia Counties accounted for over 82 percent of the wildfire-related pollution. The Volusia County Health Department and the Florida Department of Health examined the frequency of hospital visits for asthma, bronchitis, and other respiratory conditions between June 1 and July 6, 1998. Sorenson et al. (1999) surveyed seven hospitals in Volusia County and one in Flagler County in 1998 and compared admissions and emergency room visits for each county for the same period in 1997. They found that emergency room visits increased by 9 I percent for asthma and by 132 percent for bronchitis with acute exacerbation during the 1998 fire season.

Usually, this type of fine-scale health data is not recorded or easily accessible. Longer time series data would, among other things, allow hypotheses to be tested, such as whether and to what degree wildfire size, intensity, or severity affects the incidence of respiratory ailments. A complication may be that respiratory ailments also are affected by other factors associated with the kind of weather experienced during droughts, such as increased levels of dust, pollen, and fungal spores. Disentangling the specific effects of fire-created pollutants using empirical analyses is challenging, but respiratory problems represent a tangible cost that can exceed thousands of dollars per patient, and these ailments traditionally target sensitive populations such as children and the elderly.

We applied the findings of Sorenson et al. (1999) to calculate the economic effects of the 1998 wildfires on health. We assumed that the observed increases in treatment for asthma and bronchitis were the direct result of the wildfires and that these increases occurred at the same rate in the remaining counties in the St. John's River Water Management District (normalized for population differences). The additional asthma-related health care expenditures due to wildfires ranged from $325,000 to $700,000. These expenditures included costs associated with emergency room visits, inpatient care, outpatient care, and doctor's office visits. The majority of the expenditures stemmed from inpatient and emergency room care (because of data limitations we examined asthma only). Cost per treatment was calculated by dividing total expenditures by the number of visits, from Weiss et al. (1992) and Smith et al. (1997), for inpatient care and emergency room visits. Weiss et al. and Smith et al. examined a sample of asthma occurrences in 1985 and 1987, respectively, and extrapolated to determine nationwide incidence and cost. To calculate the range of expenditures from outpatient and doctor's office visits, we assume that the ratio between inpatient and emergency room visits to outpatient and office visits that occurred nationwide in 1985 and 1987 also held for 1998. We estimated that the wildfires caused the inpatient admission of 59 more people than normal, at a cost of $2,200 to

$6,300 per visit of roughly five days, and that an additional 686 patients were treated in emergency rooms, at a cost of $110 to $290 per visit. The fires also produced 80 to 800 additional doctor's office visits, at a cost of about $45 per visit, and 20 to 90 additional incidents of outpatient care, at a cost of $80 to $400 per occurrence. Because of data limitations, these numbers do not include costs associated with treatment for other conditions such as bronchitis, shortness of breath, wheezing, or other respiratory ailments that have been shown to increase during the six-week extreme wildfire season. Finally, these estimates do not include expenses paid for medications or indirect costs from lost wages.

Discussion

Based on this analysis, we predict that the 1998 wildfires will cause net damages of $300 to $500 million to the pine timber market in Florida in the long run. These are conservative estimates, as they ignore both the hardwood timber market and the general equilibrium effects that changes in the timber market have on the larger economy. The additional $280 million in estimated nontimber economic losses are also conservative estimates. Prescribed burning costs around $12.7 million annually, but how much more is being spent on other presuppression methods? FEMA considered the $100 million in fire suppression and related support to be a minimum value. Wildfire-related property losses of $10 to $12 million also provide a lower bound to actual losses, given that they do not include uninsured property losses, nor do they account for residents' time and effort spent cleaning up and repairing damaged property. Tourism losses may have lingered well past August and may have become more severe as cleanup continued and media attention persisted. Gross tourism revenue losses in August were almost as large as the combined losses of June and July.

Asthma-related healthcare costs, proxied as the cost of asthma treatment, were small compared to other economic losses. However, three important points should be made before we discard them for economic insignificance. First, it is possible that socially and politically important distributional effects exist, as sensitive populations are harmed first. Weiss et al. (1992) found that almost half of all emergency room visits for asthma were to treat children. Second, these health effects were only for the short-run costs of treatment and do not include potential longer-term health impacts. Third, they do not account for the real costs associated with pain and discomfort experienced by all people who were subject to smoky conditions.

Even given the conservative nature of our cost accounting for the 1998 wildfires, the season's total estimated impact, at $600 to $800 million, rivals the economic effects associated with category-2 hurricanes. The size of this impact underscores the importance of a complete and accurate accounting and economic analysis of such catastrophic events. In future studies of catastrophic losses from wildfire, we recommend a more detailed accounting framework than that used currently by government agencies:

1. Because more than half of the total costs of the 1998 wildfires in Florida were in timber losses, we suggest a more sophisticated evaluation of timber market impacts. This evaluation should include a more detailed tally of inventory losses, salvage volumes by species, and salvage material quality degradation, and it should include an analysis of the long-term effects on the forest sector.

2. We believe that an established system for monitoring wildfire smoke emissions in the vicinity of vulnerable populations and in conjunction with careful monitoring of hospital admission rates would enable analysts to more accurately link smoke to health impacts.

3. A refined accounting framework should include a system for performing a complete accounting of property losses, including both insured and uninsured. This is particularly important for evaluating the effects of such events in heavily populated areas and in areas where people have limited economic means.

The magnitude of our impact estimate highlights the need for mitigating

fire hazards, especially in areas where population is dense and in proximity to fire-prone forest ecosystems. Because relatively large expenses are incurred by wildfire suppression crews and emergency personnel to prevent the kinds of economic losses detailed in this article, a better understanding of actual losses can inform decisionmakers on the appropriate amount of suppression expenditures and presuppression expenditures (e.g., vegetation management activities). Enlightened wildfire policy and land-use decisions are unlikely without more complete and accurate accounting of the costs and losses to society of wildfires.

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