Prior Regulation and Post Liability as Complements:
An Application to Prescribed Burning Law in the United States

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Introduction

The use of prescribed fire faced strong resistance from policy makers and natural resource managers through much of the 20th century (Pyne 1982, Biswell 1989), but is increasingly recognized as a useful tool for increasing rangeland productivity, biodiversity, and reduction of wildfire risk and severity (Bernardo et al. 1988, Svejcar 1989, Briggs and Knapp 1995, Zimmerman 1997, Babbitt 1995, Pattison 1998). The Federal government now formally recognizes the use of prescribed fire as an integral element of wildfire management, despite the explicit recognition that it is among the most risky activities federal land management agencies utilize (U.S. Department of the Interior, U.S. Department of Agriculture 1995). The use of prescribed fire on federal land is increasing as well. Haines et al. (1998) report that the number of national forests using prescribed fire increased by 76 percent between 1985 and 1994, and project further increases in use. Between January and November 24, 2000, 4,371 prescribed burns were performed on public lands, covering a total of 1,125,306 acres (Shaver 2000). Comprehensive data of prescribed fire use on private lands is not readily available.

Prescribed burning is an inherently risky resource management tool. A prescribed fire set by the US National Park Service near Los Alamos, New Mexico in May 2000 resulted in a 48,000-acre wildfire, destroying about 220 homes and affecting about 400 families (Claims Magazine Staff Writer 2000). Litigation resulting from an escaped wildfire can be costly and time-consuming as well. For example, the plaintiff in a case (Lowe vs Jones et al., Case No. CJ 95-345) tried in Osage County, Oklahoma argued for $9.3 million in damages in a 200-acre wildfire that the plaintiff claimed resulted from a prescribed burn on adjacent property. No structures were burned, only grassland. Although no judgement was found for the plaintiff, legal and other fees for the defense approached $0.5 million.

In the absence of statutory law, the Common Law relating to prescribed fire is generally based upon negligence: to be found liable for damage to a neighbor's property, the burner must be found to not have taken a reasonable level of precaution to reduce the likelihood of damage to the neighbor's property (25 ALR5th 391). Today, virtually all states have codified civil or criminal statutory law for prescribed burning, but the structure of these laws varies substantially across states. Only four states impose strict liability on prescribed burners such that they are liable for the damage caused by an escaped prescribed fire regardless of the precautions they take to control the fire. Most states with prescribed fire statutes impose negligence rules of some form on the prescribed burner, but again, these negligence rules vary substantially across states.

Different liability rules induce different incentives for both prescribed burners and potential victims of escaped fire or smoke. Using a model adapted from the law and economics literature, we examine the incentive effects of a number of liability rules commonly imposed to address the problem of external property damage due to prescribed fire, and discuss their relative efficiency under various technological, demographic, and informational environments.

Not only do prescribed burning laws vary substantially across states, but these laws currently are in flux. The laws in most states have been revised since 1990, and a number of statutes are currently under review. The intent of this paper is to provide a useful conceptual framework for further development and refinement of prescribed burning liability law. In particular, we focus on the extent to which both *ex ante* regulation of prescribed fire, such as permit systems, prohibitions, and criminal penalties, and *ex post* liability via litigation, are used as substitutes or complements in the management of external costs of prescribed fire use.

A model of liability for prescribed burning

Consider two neighboring risk-neutral property owners, one who intentionally applies a prescribed burn to her land, and a neighbor whose property would suffer damage if the fire managed to escape onto his land. Suppose the probability of an escaped fire depends on precaution effort by the burner, and the extent of damage — given that a fire escapes — depends on the mitigation and preparation effort taken by the victim. The following model is adapted from Brown (1973).

First consider the efficient (wealth maximizing) levels of precaution; we will then examine the effectiveness of various liability rules for inducing this allocation. The total net value of a prescribed burn, Π, is the value of the benefits from the burn minus the expected value of damage and any the costs of care incurred by the burner and victim:

$$\Pi = R - D(V) \cdot P(B) - W^v V - W^b B \tag{1}$$

where

- $R > 0$ = the value of the burn to the burner,
- $D(V)$ = damage to the victim if fire escapes,
- $P(B) \in (0, 1)$ = probability of an accident,
- V = the level of care invested by the victim,
- B = The level of care invested by the burner,
- W^v and W^b = Cost of a unit of care for the victim and burner, respectively.

V might include fire-proofing buildings, clearing combustible materials from around buildings, and evacuation effort in case of fire or smoke. B might include the use of inputs such as making fire breaks, and assuring water availability for any errant sparks. Waiting for low temperature and reasonable wind conditions is an important factor that can be considered a costly input as well.

The first-order condition for maximization implicitly defines the economically efficient level of care for each party:

$$-D'(V) \cdot P - W^v \leq 0 \tag{2a}$$

$$-D \cdot P'(B) - W^b \leq 0. \tag{2b}$$

P and D are abbreviations for the functions $P(B)$ and $D(V)$, and necessary curvature conditions to ensure a maximum are $D'(V) < 0$, $P'(B) < 0$, $D''(V)P > 0$, $DP''(B) > 0$, and $DPD''(V)P''(B) - [D'(V)P'(B)]^2 > 0$.

The first-order condition for the victim is represented by equation 2a. The first term in the equation, $-D'(V)P$, is the expected value of the marginal product of care (VMP) by the victim in terms of reductions in expected damage. A VMP curve sufficiently high relative to the marginal cost of care (W^v) will result in a positive optimal level of victim care. A low VMP will result in a corner solution with the optimal level of care by the victim being zero. An analogous relationship pertains to the burner.

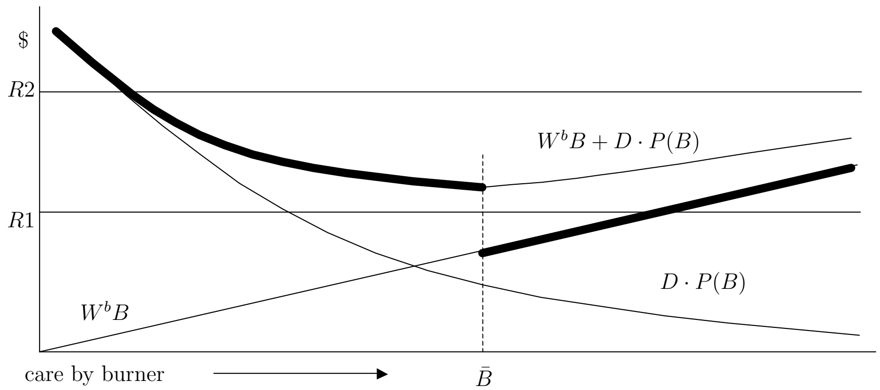
Three additional implications become clear from a dissection of the marginal value of precaution for the two participants. First, when the equilibrium value of P is low, the marginal productivity of victim care is low and it is less likely to be economically efficient for victims to expend any effort preparing for escaped prescribed fire. Second, if the value of potential damage to neighboring property (D) is low, it is more likely that the efficient level of care by the burner is zero (B=0). Third, the marginal product functions $D'(V)$ and $P'(B)$ also affect the optimal level of care for each participant. If the technologies used to reduce either the probability of escape or the extent of damage are ineffective or are costly, the levels of these inputs should for efficiency's sake be lower, and possibly zero. Finally, notice that precautionary levels of B=0 and V=0 could be efficient even if the expected net benefit of a fire is positive.

Strict liability

The model presented above provides a framework for understanding the incentive effects of different liability rules. Strict liability will be considered first, followed by an analysis of negligence rules.

With no legal intervention and no interaction between the victim and the burner, liability for damage is in effect borne by the victim. Alternatively, if the burner were required to

Figure 1: Cost function for B.



completely compensate the victim for damage (a strict liability rule), the victim suffers no damage and would have no incentive to invest in reducing the probability of damage. Thus, the first first-order condition in (2a) would only be satisfied if the victim had little influence over damage to his own property, the probability of damage is low, or the costs of damage abatement are high ($D'(V) \cdot P \leq w^v$). A strict liability rule is efficient if and only if the victim cannot effectively reduce the probability of the damage occurring.

Negligence

Now consider a negligence rule, where the burner is not liable for damage if B is greater than or equal to some standard $\bar{B}$. For any given level of V, the expected cost to the burner subject to a strict liability rule is $W^bB + D(V) \cdot P(B)$. If the burner satisfies the negligence rule ($B \geq \bar{B}$), she will only accrue her input costs, W^bB. If the burner does not satisfy the rule, her costs will be $W^bB + D(V) \cdot P(B)$. This cost function is represented by the thick line in figure 1, which is discontinuous at $\bar{B}$. In the figure, $\bar{B}$ is set to minimize the total expected cost of the prescribed burn, which is the economically efficient negligence standard.

The burner will expend just enough effort to satisfy the negligence standard as long as the negligence standard is not too high. Suppose, for a moment, that this is the case. The burner chooses $B = \bar{B}$, and the liability will fall on the victim. We are assuming complete information, so the victim will know that the burner will exert just enough care to satisfy the liability rule. Therefore, the expected cost to the victim will include the full expected damage of the burn, which induces the victim to exert the optimal level of care (defined by equation 2a).

To burn or not to burn

The results above relate to the allocation of effort *given* that a prescribed fire is set by the burner. The decision whether or not to burn is also affected by the liability rule. The burner will decide to burn if the private net gains of doing so given equilibrium effort levels are positive.

Strict liability will internalize all expected damage due to both the number of fires started and the level of care (Shavell 1980), because the burner internalizes the expected damage every time a fire is lit. The victim, on the other hand has no incentive to reduce expend precautionary effort. If the victim should for efficiency's sake expend precautionary effort, then the total expected costs of the burn will be inefficiently high. If R falls *above* the minimum total expected costs given efficient levels of B and V, but *below* the minimum total expected costs given V=0, the burn will not be performed even though it would be efficient to do so given efficient precaution by the victim. In other words, when the net benefits of prescribed burning tend to be low, a strict liability rule will tend to result in too few prescribed burns if the victim can mitigate expected damage.

In contrast, under a negligence rule based on precautionary effort, a burner may light a fire when the total costs of doing so outweigh the benefits. Figure 1 shows how a negligence rule may result in too many prescribed fires. $R2$ represents a level of benefit that covers both the costs of care and expected damage. From an efficiency perspective this fire should be set. $R1$ covers the costs of care borne by the burner in order to satisfy the negligence rule, so the fire will be set. However, because the costs including expected damage are larger than $R1$, an efficiency criterion dictates that the fire should not be set. Thus, a fire will be set when it is inefficient to do so if the benefits to the burner lie between the costs of the optimal level of care $W^b B^*$ and the total expected costs $W^b B + DP(B^*)$. For any given distribution of R, this is more likely if the net benefits to the burner are positive but small, and when expected damage is large.

At least two approaches might be used to address the incentive to start fires too often under an input-based negligence standard. The first approach is a negligence rule based on the total net value of starting a fire. This form of negligence rule is known as the Learned Hand rule. It requires a burner to be found negligent if she ignites a fire when the expected total net benefits (including expected damage) are negative, and not negligent otherwise (Feldman and Frost 1998). An analogy to a simple model of a firm may help to clarify the difference between these two types of negligence rules: the Learned Hand rule is like a shut-down rule: produce(burn) if the net value of production (burning) is positive whereas an input-based negligence rule defines the optimal allocation of resources (inputs) *given* that the burn is carried out. A Learned Hand rule cannot induce efficient precautionary effort, and an input-based negligence rule cannot ensure that burns will not be performed when their net social benefit is negative.

The second approach is to support the negligence rule with *a priori* regulation: require burners to acquire a permit before burning. Presumably, this permit would only be issued if the expected social net benefits of the burn are positive. Acquisition of these permits may also be contingent on proof of some level of preparation, and may be used as explicit elements of a negligence standard if litigation ensues, thereby facilitating pretrial settlement and minimize court costs.

The relative value of these two options (permits or the Learned Hand Rule) depends on how costly they are to implement. If information about expected net social benefits were readily available prior to a burn, then they would likely be readily available after the burn as well. Further, there is no clear reason to believe that more information on *expected damage* would be available after an escaped fire. Therefore, we must look elsewhere to explain the structure of regulation and law.

Prior regulation and Post Liability: Substitutes or Complements?

At least two papers have developed economic models of the tradeoffs and incentive effects of regulation and liability, and they each take different approaches. The first paper, Shavell (1984), argues that given variation in the extent of variation in potential damage across injurers, the simultaneous use of *ex ante* regulation and *ex post* liability can be explained by the potential for bankruptcy and the probability that a burner will not be taken to court even if an escaped prescribed fire causes. The second paper, Kolstad et al. (1990), do not consider bankruptcy and non-litigation, but instead base their arguments on the uncertainty that the injurer faces about the outcome of a trial, given the injurer's expectations about the potential for damage.

In general, common law has relied on negligence rules rather than strict liability (25 ALR5th 391) with respect to the use of prescribed fire. The question, then, is why statutory negligence rules were adopted in so many states when common law already supported negligence rules. One possible answer follows from Kolstad et al. (1990). Their model suggests that if there is uncertainty about the outcome of judicial rulings ("evidentiary uncertainty"), negligence rules alone (without prior regulation) will lead to too little precautionary effort on the part of potential injurers if uncertainty about the judicial ruling is sufficiently large. This is the case even if judicial rulings about the negligence standard are, on average, set at the efficient level. If a statutory rule can reduce uncertainty by providing a clear set of unbiased standards within a state by which both the litigants and the courts can judge their actions, the inefficiency of a negligence rule may be reduced.

Two things are clear from a reading on statutory law for prescribed fire: first, some statutory negligence standards appear to be designed to clarify negligence standards; second, that uncertainty cannot be removed completely. Given that this is the case, consider now the addition of *ex ante* regulation. Despite the differences in their underlying assumptions, both Kolstad et al. (1990) and Shavell (1984) come to the conclusion that the joint imposition of negligence rules and prior regulation can provide efficiency gains over the use of either instrument alone under certain circumstances. In particular, Kolstad et al. (1990) find that as long as a negligence rule alone tends to lead to too little precaution, the further imposition of prior regulation at a somewhat lesser standard of care will tend to lead to a higher (more efficient level) of care. Thus, liability rules and negligence rules act as complements. Kolstad et al. (1990) also find in such circumstances that joint use of liability and regulation improves on liability alone if the the marginal cost of care for the potential injurer is large. On the other hand, both Shavell (1984) and Kolstad et al. (1990) suggest that if evidentiary uncertainty is small, and/or the marginal cost of precaution is small, then prior regulation and liability should be used separately.

Discussion

Statutory law related to prescribed burning is currently in a state of flux. In the following section we examine current statutory law in the context of our model. We begin with a discussion of variation in law across space and time, and then look more closely at specific statutory negligence rules and economic logic behind these rules. The discussion is motivated by two goals: to provide an economic basis for current statutory law, and to support our model as a prescriptive policy tool.

Table 1 includes selected categories of fire liability laws and a listing of the states whose statutes include them. The first three categories are prescribed fire liability rules in order of increasing stringency from the burner's perspective: 1) strict liability, (2) negligent unless proven otherwise and (3) not negligent unless proven negligent. The latter two are different in that in (2) the burden of proof is on the burner (defendant) given that the burner's fire escaped from his or her property, and in (3) the burden of proof is on the victim (plaintiff).

Four states impose strict liability on prescribed burners — Connecticut, North Dakota, New Hampshire, and Oklahoma. If a fire escapes, the burner is liable for damage regardless of his or her effort to contain the fire. Twenty-two states have some form of negligence rule in

Table 1: State liability law for prescribed fire and fire risk.

Liability or property rule	State
Burner strictly liability	CT, ND, NH, OK.
Burner presumed negligent if fire escapes.	AK, GA, MD, OR, UT.
Burner liable for damage if proven negligent.	AL, AR, CA, DE, FL, LA, MS, ME, MI, NC, NJ, OR, TX, VA, WA, WI.
Notification requirements ([N]=neighbors, [A]=agency)	AR[N,A], CO[A], LA[N], NY[N], NC[N], TN[N], UT[A].
Permits or bans supported by statute	AL, AZ, CA, CO, CT, FL, GA, ID, IA, ME, MA, MN, MS, NE, NV, NH, NJ, NY, OR, RI, SD, UT, WV, VT, WA.
Criminal penalties for leaving fire unattended or failure to extinguish and negligent escape.	CA, MI, NJ, NM, NV, NC, OK, OR, SC, SD, TN, UT, WI, WY.
No statutes addressing prescribed fire	HI, IL, IN, MO, MT.
Liable for negligently allowing uncontrolled spread of wildfire	AK, DE, MI, OH, OR, PA, SD, TN, TX, UT, VT, WA, WV.
Uncontrolled fire is a nuisance: can be billed for public fire suppression costs.	CO, GA, ID, MS, NH, ME, MD, OK, OR, WA, WI.
Regulations restricting excessive vegetative fuel loads	MN, MT, NM, WA.

their statutory code. Six of these states place the burden of proof on burners in that escaped fire is *prima facie* evidence of negligence; the burner must show due care to escape liability for the damage. Sixteen states place the burden on the plaintiff to prove negligence on the part of the burner in order to receive damages. Oregon falls in both of these categories, allowing plaintiffs to collect double damages if the burner is proven negligent or single damages if no proof of negligence and no proof of due care. Eleven states treat uncontrolled fire as a nuisance, requiring landowners to pay for the cost of fire suppression by public agencies.

A number of state statutes support penalties or liability for fires escaping from one's own land even if the fire is not intentionally set (table 1). For example, Michigan law states that anyone who willfully allows a fire to pass from his property to another's property is guilty of a felony. Furthermore, some states impose liability or penalties for excessive fuel loads on their land. For example, Montana statutes focus extensively on requirements for mitigating fire hazards during timber harvest activities. Wisconsin (and other states) require railroad companies to mitigate fire hazards along railways to reduce the probability of fire from locomotive sparks.

Strict liability versus negligence rules

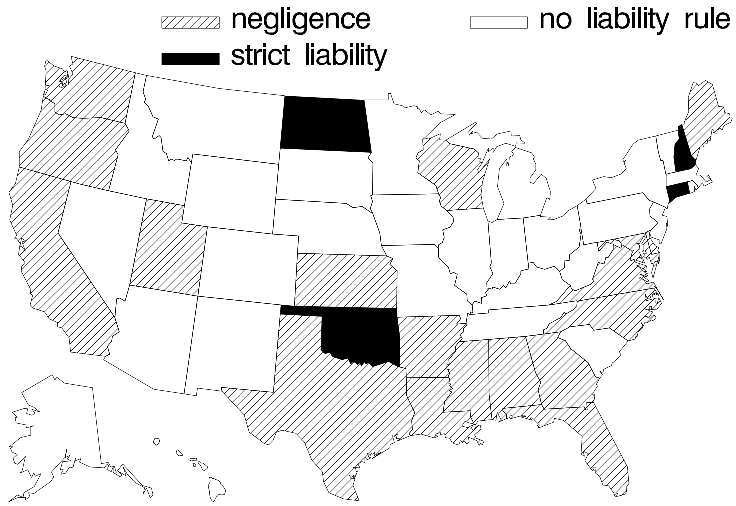
Our model implies that strict liability is likely to induce efficient mitigation effort and frequency of prescribed fire use if burners have most or all control over the likelihood of damage due to prescribed fire, when it is not cost-effective for potential victims to reduce potential property damage from fires. As shown in table 1 and figure 2, twenty-two states explicitly impose negligence rules and only four impose strict liability on burners. This distribution of liability rules is consistent with a recognition by policymakers that potential victims generally have some control over the extent of damage that might be sustained as a result of prescribed burning, despite the risk of external costs in the form of damage from escaped fire.

Negligence rules

Negligence rules vary substantially across states and across time. Statutory rules relating to prescribed fire often contain an ambiguous statement requiring "due care", as well as more specific rules that are necessary (but not sufficient) to satisfy due care.

One common specific rule, the requirement to notify neighbors, has already been discussed. The economic logic behind this rule is as follows. If landowners expect to be notified of their neighbor's intentions of prescribed burning, they need only be on alert for escape from prescribed fire when such a fire is planned (and reported). This undoubtedly lowers

Figure 2: Liability rules for prescribed fire in the United States



their overall mitigation costs, because time-sensitive mitigation of potential damage (clearing dry vegetation near a house that might contribute to the extent of damage, for example) may then be performed only when the potential for an escaped prescribed fire exists, and need not be applied at other times. Furthermore, the cost to a burner of notifying adjacent landowners is likely to be relatively low. As a result, notification of neighbors will reduce the overall expected costs of a prescribed burn.

Another common specific requirement that burners must remain with the fire until it is completely extinguished ("dead out"). The cost to a landowner (or the landowner's agent) for remaining an additional hour or day on a burn sight is likely be relatively low compared to the expected costs of the resurgence of an unattended smoldering fire. The crucial point here that leads to such a requirement is that without such a negligence standard, the costs of a burner leaving a site prematurely would likely be borne at least to some extent by a neighboring landowner rather than the burner.

Specific negligence rules for cost-effective inputs such as notification and on-site presence are consistent with our model, because it is unlikely that the costs of such precautions will outweigh their expected benefits (i.e. reductions in expected damage). Statutory specification of these rules will provide a higher degree of certainty about negligence requirements, thereby more effectively inducing proper precautionary incentives and reduce transaction costs of court proceedings.

An important characteristic of court negligence findings is that courts usually distinguish between foreseeable factors and abnormal or unforseeable factors contributing to the spread of fire, such as abnormal changes in wind patterns (speed and direction). Our model suggests that the probability of the fire spreading to neighboring lands should be considered when establishing negligence. This probability is in turn based in part on expectations about exogenous factors such as wind. When deciding whether a burner started a fire negligently, courts generally base their decisions on the information burners at the time the fire was started. A burner may be found negligent if prevailing winds were unsatisfactory when the fire was lit, but generally would not found negligent for the spread of fire resulting from an abnormal and unforeseen change in the wind patterns (25 ALR5th 391).

Permits and regulatory requirements

Regulatory restrictions and permits are property rules providing landowners with the right to burn only if they satisfy a set of requirements delineated by statute and regulatory agencies (we ignore issues of criminal intent in this paper to focus on the law relating specifically to productive burning). Otherwise, the burner may be subject to criminal penalties. These are different from liability rules, where burners have the right to perform prescribed burns but must bear the liability associated with the burn.

Property rules for prescribed burning are imposed for two general types of activities: for burning without a permit or contrary to permit stipulations, and for leaving a fire unattended or for negligent escape and failure to extinguish. Most states maintain a permit system for prescribed burning under some circumstances. In some states, satisfaction of permit requirements is necessary to avoid potential fines and other criminal penalties. To acquire a permit, the landowner may have to show sufficient knowledge, preparation, and notification of neighbors or public fire-fighting entities. Colorado's statute, for example, states that permits are to be issued based on the proximity of the planned burn to buildings, the potential contribution of the fire to air pollution, climatic conditions, and other related factors. These requirements, when used in conjunction with a negligence rule, are consistent with our model.

Coincidence of Regulation and Liability

As is the case with many environmental issues, *a priori* regulation and *ex post* liability are used simultaneously in many states to address prescribed fire externalities. The question of whether these two instruments are used simultaneously has implications regarding the present model and that of Kolstad et al. (1990). In particular, Kolstad et al. (1990) suggests that if there is substantial evidentiary uncertainty or if the marginal costs of precaution are very high, regulatory restrictions and negligence rules should be used simultaneously. Otherwise, they should be used separately.

In order to shed some empirical light on this relationship in the context of prescribed burning, Fisher's exact test for independence was computed to examine the correlation among a number of measures of prior regulation and negligence rules (please note: this aspect of the paper more than other sections is very preliminary). our sample was based on statutory regulation and liability law for all 50 states (n=50). In the first test, we generated a dummy variable called REGULATION, which equals one if state laws required permits based on explicit input requirements and zero otherwise, and another dummy variable that equals one if the state has imposed a statutory negligence rule. We found that permit systems appeared to be used where negligence rules were not; that is, permit systems and statutory negligence rules appear to be used as substitutes. However, this relationship is weak, and Fisher's exact test failed to reject the null hypothesis of independence at any reasonable level. Similarly, Permit systems tend to be used when strict liability rules are not, although again, the null hypothesis of independence is not rejected.

A new generation of prescribed fire statutes

A new generation of prescribed fire statutes have been developed in the southeastern states beginning with Florida in 1990 (Brenner and Wade 1992). The Florida statute goes to great length to recognize prescribed burning as a useful land management tool. The legislation explicitly recognizes ecological benefits, and benefits from reducing the likelihood and severity of wildfires. It explicitly recognizes prescribed burning as a property right, subject to a relatively detailed set of precautionary requirements. Finally, it specifies that landowners are not liable for damage or injury caused by escaped fire or smoke unless found to be grossly negligent. Other southern states to explicitly recognize prescribed burning as a beneficial property right include Georgia, Louisiana, Mississippi, and North Carolina. In the context of our model, the explicit recognition of the value of prescribed burning acts to emphasize the possibility that R^i in figure 1 is high, arguably increasing the likelihood that the Learned Hand rule is found by the courts to be satisfied. The requirement of gross negligence arguably lowers $\bar{B}$ relative to not requiring gross negligence. These statutes are therefore consistent with an apparent attempt to reduce the likelihood of prescribed burner liability.

To the extent that reduction of fuel loads resulting from controlled burning reduces the likelihood and severity of wildfires, prescribed burners may contribute positive externalities by reducing their potential fuel contributions for wildfires moving across numerous landholdings in a region. If this conjecture is correct, we would expect this type of statutory response in areas where prescribed burning can reduce the total social costs of fire generally (that is, the net cost of prescribed fires plus the costs of wildfires and their control). Although a formal analysis of the geographic and demographic distribution of negligence rules across states is beyond the scope of this paper, figure 2 shows that southern and pacific states have had a greater tendency to introduce negligence standards and explicit support of prescribed burning than northern states.

Conclusion

Prescribed fire is a land management tool with long historical roots in North America, Australia, and elsewhere, and a resurgence in interest from natural scientists, public land managers, and legislators has led to substantial changes in the statutory law of many states in recent years. We develop a model for comparing the relative economic efficiency of liability rules, provide a summary of current statutory law relating to prescribed fire in the United States, and discuss our findings in the context of the model. Many states have adopted statutory negligence rules despite the fact that negligence rules had already been adopted through common law rulings. Many states have also adopted regulatory restrictions on prescribed burning, but the two forms are not necessarily used together as Shavell (1984) and Kolstad et al. (1990) might suggest.

Most of the recent changes in statutory law relating to prescribed fire provide substantial support for prescribed fire as a land management tool despite the risks associated with its use. Factors supporting these changes may include increasing evidence that prescribed fire can be a cost effective means of controlling wildfires, promoting plant biodiversity, and increasing pasture and timber productivity. Nonetheless, application of prescribed fire becomes more costly and risky with increasing suburbanization and accompanying land and land tenure fragmentation. The incident at Los Alamos, New Mexico described at the beginning of this article is just one illustration of these potential complications.

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