Prescribed Burning for Forestry and Wildlife Short Course

MISSISSIPPI STATE UNIVERSITY™
EXTENSION

Course Instructors and Participants

May 17, 2019
9:00 am – 2:00 pm

Attala County Extension Office

Sponsors:

Sustainable Forestry Initiative
Attala County Forestry Association
Mississippi State University Extension

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PRESCRIBED BURNING FOR FORESTRY AND WILDLIFE:

Course Agenda*

Friday – May 17, 2019

8:30 – 9:00 am:	**Registration**
9:00 – 9:10 am:	**Sustainable Forestry Initiative**
9:10 – 9:40 am:	**Offsetting the Cost of Prescribed Burning** (John Gruchy – MDWFP)
9:40 – 10:25 am:	**Prescribed Fire for Wildlife Habitat Management** (John Gruchy – MDWFP)
10:25 – 10:35 am:	**Break**
10:35 – 11:00 am:	**Burning Legally in Mississippi** (Brady Self – MSUE)
11:00 – 11:30 am:	**Safety Considerations for Prescribed Fire** (Brady Self – MSUE)
11:30 – 12:15 pm:	**Environmental Considerations for Fire** (Don Chance – MDWFP)
12:15 – 12:45 pm:	**Lunch**
12:45 – 1:15 pm:	**Creating Burn Plans** (Brady Self – MSUE)
1:15 – 2:00 pm:	**The Risks and Rewards of Prescribed Fire** (John Willis – MSUE)
2:00 – 2:15 pm:	**Final Questions, Evaluations, and Wrap Up**
2:15 pm:	**Adjourn**

*4.5 Hours - Category A BORF CFE credits for foresters
*4.5 Hours – Category 1 CLE credits for professional loggers

Supplementary Reading Sections:

Section 1: Speaker Handouts:

1: Sustainable Forestry Initiative
2: Offsetting the Cost of Implementing Prescribed Fire
3: Prescribed Fire for Wildlife Habitat Management
4: Burning Legally in Mississippi
5: Safety
6: Fire Behavior and Weather
7: Firing Techniques
8: Creating Burn Plans
9: Prescribed Fire in Pine and Hardwood Systems

Section 2: Supporting Literature

1. Prescribed Burning in Southern Pine Forests: Fire Ecology, Techniques, and Uses for Wildlife Management
2. When Will a Prescribed Burn Help My Pine Stand?
3. Legal Environment for Prescribed Burning in Mississippi
4. Living with Fire: A Guide for Mississippi Homeowners
5. Prescribed Burning for Pasture Management
6. A Review on the Dynamics of Prescribed Fire, Tree Mortality, and Injury in Managing Oak Natural Communities to Minimize Economic Loss in North America
7. Fire Damage Effects on Red Oak Timber Product Value

Speaker Handouts

SUSTAINABLE FORESTRY INITIATIVE®

1. The Sustainable Forestry Initiative or SFI is the largest forest certification program in North America. SFI delivers positive results in the marketplace and helps our customers feel good about buying our forest products. The SFI label is now on over 6500 forest products and SFI certifies over 250 million acres of forestland. In Mississippi we have 32 member companies that have implemented SFI standards.

2. Our SFI member companies agree to these principles and are third party audited to make sure they walk the talk. If you ever see any inconsistent practices please report them to MSU/SFI Logger Education hotline 601-325-6852. Two of these principles directly benefit family forests. #1. Mississippi's professional logging force is trained to SFI Responsible Fiber Sourcing standards. Loggers are required to follow Mississippi's Forestry Best Management practices. #2. SFI member companies help fund training and education programs for family forests including this one.

3. Great news for family forests was SFI's decision to count fiber from Tree Farm-certified forests as certified content for SFI label use. That gives Tree Farm certified wood preferential treatment in the marketplace but it cannot guarantee a higher price. So you are encouraged to certify your family forest through the Tree Farm program and help broaden sustainable forest management across the state. We all benefit.

Barriers to fire implementation

APATHY / IGNORANCE

FEAR

UNCERTAINTY

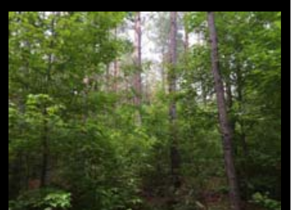
RESOURCE LIMITATIONS → TIME, LABOR, MONEY

Managing Time – Burn Days

Don't waste time = clear goals
- **Is burning the best practice?**
- **Are burns even effective?**

Minimize constraints
- **365 day burn season!**

Be prepared
- **Address firebreaks and fuel hazards sooner than later**
- **Time spent in preparation will speed up burning**



Managing Labor – Help on burns

What are the labor limitations
- **Trained burners vs. line crew**
- **Equipment / Operators**

Prepare to reduce labor burdens
- **Wide, bare dirt, firebreaks**
- **Square up units / keep small**
- **Proper equipment**

Neighbors helping neighbors
- **Prescribed Burn Association**
- **Talk across the fence**

Managing Costs

Prioritize appropriately
- **Professionals for difficult burns**
- **Avoid low return projects**

Apply for multiple sources of cost-share

Work with CPA to determine deductible expenses

High-earners might consider conservation easements

Managing Costs – Cost-share

USDA-NRCS
- **EQIP – Apply before October, good rates**
- **CSP – More complicated than just burning**

USDA-FSA
- **CRP Mid-Contract Mgt. – Restrictions apply**

MS Forestry Commission
- **FRDP – limited funding**
- **Hazard Mitigation – 10 addresses w/in 2 miles**
- **Community Protection – 10 miles from USFS**

USDA – Forest Service
- **Good Neighbor Authority**

Prescribed for Wildlife Habitat Management

What is Habitat?

The environment where and animal lives

Includes…

food
water
cover
space

…in an arrangement that is useable to wildlife

The Animal Niche

It's how an animal makes a living (food, cover)

It's what an animal does (behavior, physiology)

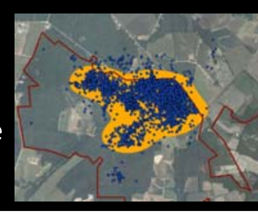
Animal must capitalize on its adaptations (strategy)

Scale of Management

Home Range
 Core Area
 Excursions

Seasonal Habitat Use
 Need vs Availability
 Breeding
 Migration

Landscape and Patch Size
 Ownership(s)



Fire and Basal Area

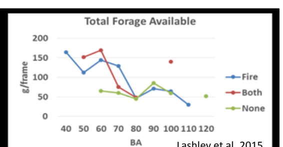
Impossible to **maximize** timber and wildlife habitat on the same acre

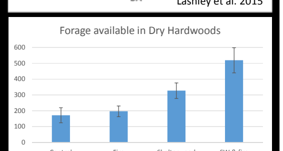
Interactions exist between BA and disturbance

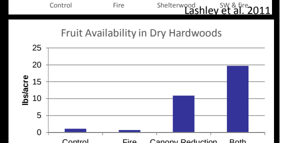
How much forest needed?

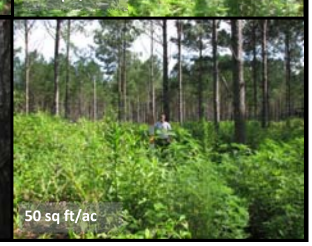
Scale/arrangement critical

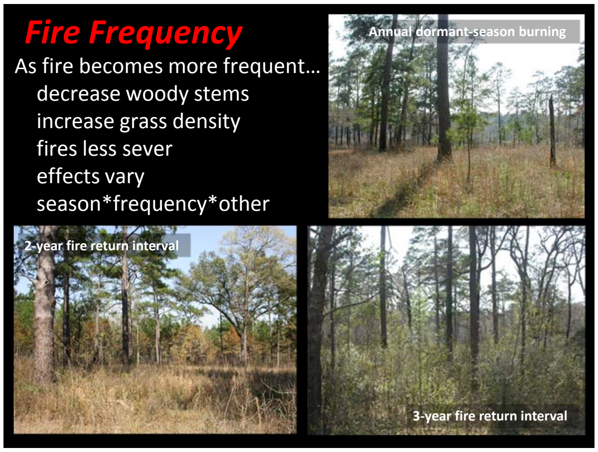
Management is the key



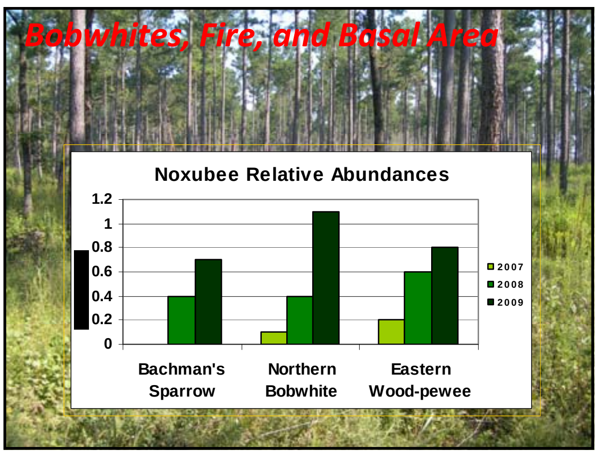


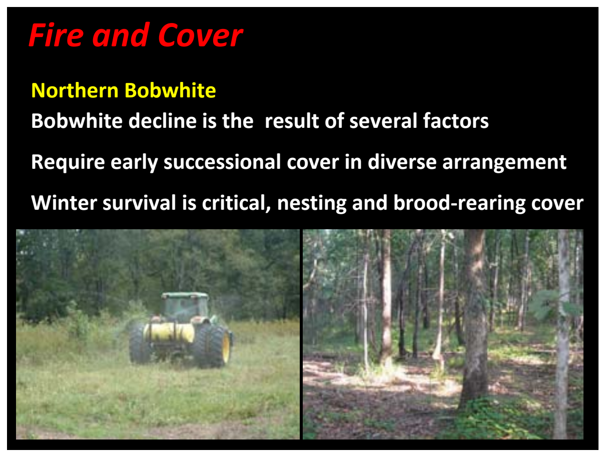


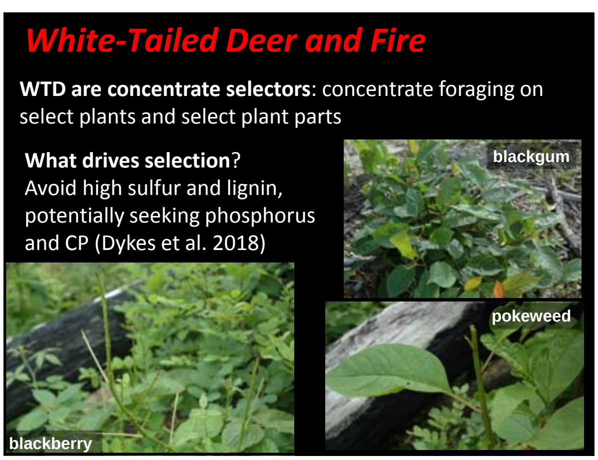


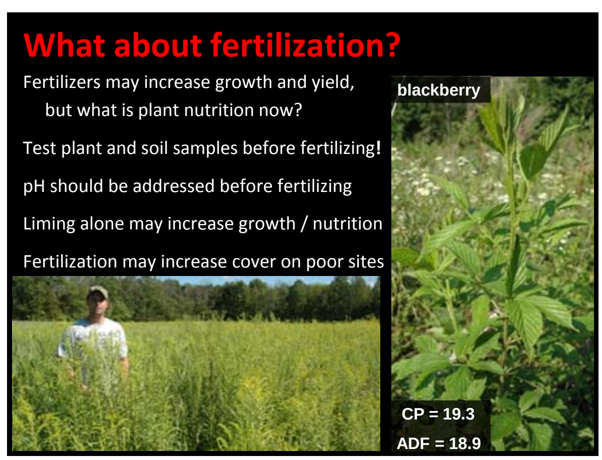

Fire Frequency
As fire becomes more frequent…
decrease woody stems
increase grass density
fires less sever
effects vary
season*frequency*other
Annual dormant-season burning
2-year fire return interval
3-year fire return interval


Fire Season
Growing-season fire to control woody plants
Dormant-season fire to stimulate new growth
Dormant burning March-April
Growing burning May-Sept
October
May
March


Bobwhites, Fire, and Basal Area
Noxubee Relative Abundances
1.2
1
0.8
0.6
0.4
0.2
0
Bachman's Sparrow
Northern Bobwhite
Eastern Wood-pewee
2007
2008
2009

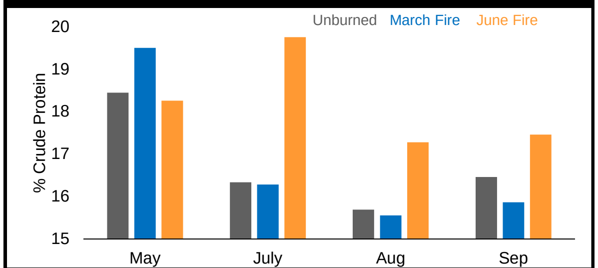

Fire and Cover
Northern Bobwhite
Bobwhite decline is the result of several factors
Require early successional cover in diverse arrangement
Winter survival is critical, nesting and brood-rearing cover


White-Tailed Deer and Fire
WTD are concentrate selectors: concentrate foraging on select plants and select plant parts
What drives selection?
Avoid high sulfur and lignin, potentially seeking phosphorus and CP (Dykes et al. 2018)
blackgum
pokeweed
blackberry


What about fertilization?
Fertilizers may increase growth and yield, but what is plant nutrition now?
Test plant and soil samples before fertilizing!
pH should be addressed before fertilizing
Liming alone may increase growth / nutrition
Fertilization may increase cover on poor sites
blackberry
CP = 19.3
ADF = 18.9

Fire and Forage

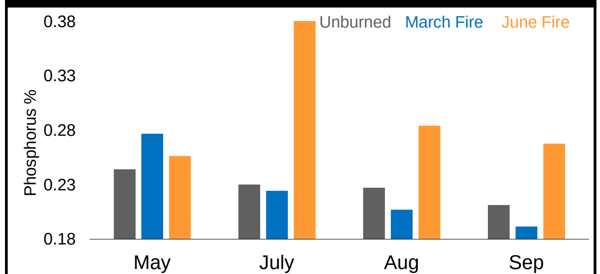
Fire Timing Affects Crude Protein - Within Month
(Blackberry, Poison Ivy, Late Boneset, Green Ash, Goldenrod)



Nichols et al. 2019

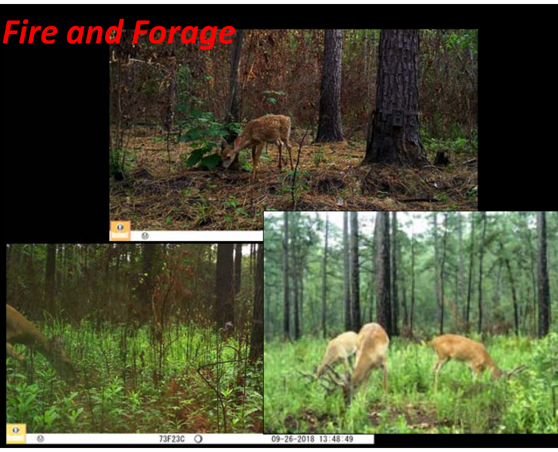
Fire and Forage

Fire Timing Affects Phosphorus
(Blackberry, Poison Ivy, Late Boneset, Green Ash, Goldenrod)



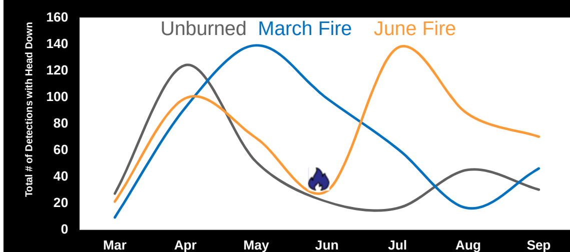
Nichols et al. 2019

Fire and Forage



Fire and Forage

Activity Curve – Photos of Feeding Deer



Nichols et al. 2019

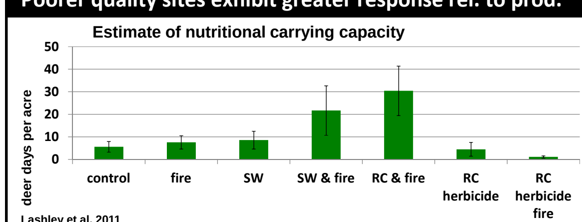
Forbs are most important

- This is what deer eat!
- 70% of diet in spring/summer
- Provides structure
- Fawning cover

Fire and Forage

White-tailed Deer

- Composition of understory important
- Intensive foliar herbicide applications can reduce browse
- Nutrient response may vary based on timing of fire
- Poorer quality sites exhibit greater response rel. to prod.



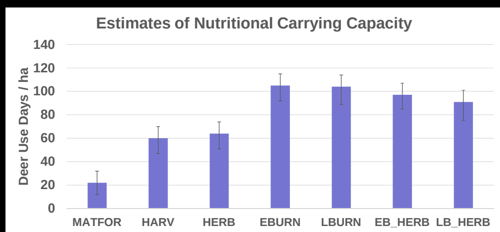
Disturbance and Forage

White-tailed Deer

What about maintaining clearcuts as early succession?

Heavily dependent on site characteristics

Herbicides can help steer composition from woody plants



Nanney et al. 2019

Wild Turkeys and Fire

Weak selection at patch scale, landscape > heterogeneity

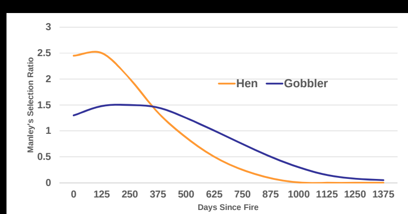
Primarily use recently burned areas for brood-rearing and foraging and foraging, rougher areas = nesting

Fire and Cover

Wild Turkey

Turkey selection is very seasonal and difficult to follow

Utilize BLWH and UM forest, but appear to select recently disturbed forests during pre-nesting and brood-rearing



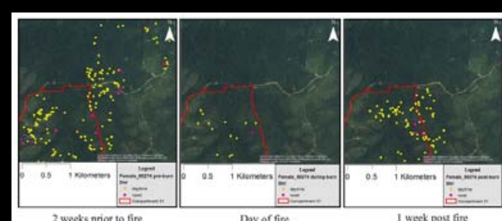
Martin et al. 2012

Fire and Cover

Wild Turkey

Hens may roost young broods in unburned stands

Burn block size may be important



Yeldell et al. 2017

Burn Unit Size and Rotation

General guidelines

Potential negative impacts of fire to game species are often mitigated by burn units ≤100-acres

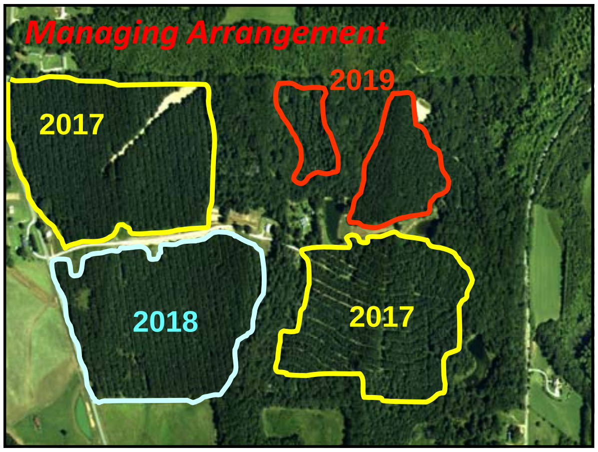
May vary based on orientation of burn units, season of burn, techniques, areas that exclude fire (i.e., drains)

Managing Arrangement

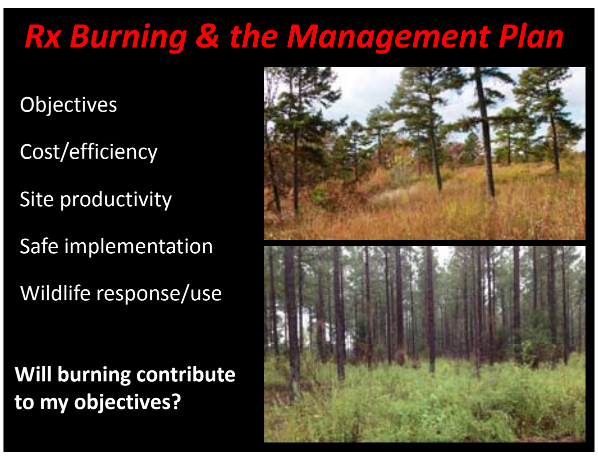
Managing stands < 100 acres best for small game. > ok WTD & WT

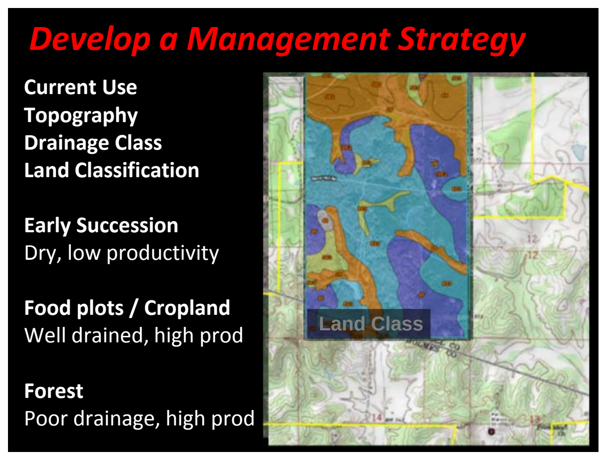
Multiple stand types, age-classes, and fire regimes add diversity

Corridors are key for attracting animals in hunting scenarios


Managing Arrangement
2019
2017
2018
2017


Forest openings
unplanted openings


Rx Burning & the Management Plan
Objectives
Cost/efficiency
Site productivity
Safe implementation
Wildlife response/use
Will burning contribute to my objectives?


Develop a Management Strategy
Current Use
Topography
Drainage Class
Land Classification
Early Succession
Dry, low productivity
Food plots / Cropland
Well drained, high prod
Forest
Poor drainage, high prod
Land Class


Develop a Management Strategy


Develop a Management Strategy

Develop a Management Strategy

Questions?

www.mdwfp.com/privatelands

John Gruchy
662-274-1050
john.gruchy@wfp.ms.gov

Burning Legally in Mississippi

Brady Self
Northwest Mississippi Extension Forestry, Grenada
662-226-6000 or brady.self@msstate.edu

Definition

- Prescribed burning/fire is the **controlled** application of fire to naturally occurring vegetative fuels for ecological, silvicultural, and wildlife management purposes.

Prescribed burning is fire that is:

- Applied in a skillful manner
- Under exacting weather conditions
- In a definite place
- For a specific purpose
- To achieve (certain) results

Fire in History

- Native American burning
  - Visibility, Mobility, Wildlife
- Early-European burning
  - Agriculture

Age of fire suppression

- Only YOU!
  - 1940s

Common Law

- Property Law
  - Land owners have right to use their land as they see fit in relation to others in society.
    - Right to intentionally set fire for mgt purposes.
- Tort Law
  - One person's behavior causes injury, suffering, unfair loss, or harm to another person.
  - Intentional, Negligence, or Strict Liability.
  - Compensate the victim or discourage repeated violations.
  - Civil harms occurring to people or property .
  - Provides remedy to resolve dispute btwn injurer and victim.
  - Prescribed burning falls within negligence tort rules.

Simple Negligence

Rules allow defendant to reduce/avoid liability based on whether "all standards of care" were satisfied. "Actions of a reasonably prudent person."

- Proving negligence requires:
  - Duty – obligation owed to act in non-negligent manner towards others
  - Breach of Duty (i.e. fault) – non achievement of #1
  - Causation – connection btwn defendant and loss sustained by victim
  - Loss – plaintiff must prove actual loss has been suffered

Proving Negligence

If the minimum was not achieved, it can be argued that negligence does not even have to be proven – "negligent per se" (e.g. automatically negligent)

If minimum requirements are met, plaintiff must prove negligence.

Even if minimum standards set forth in MS PBA 1992 are met, negligence can still be proven.

Determining Negligence

Were the precautions of a reasonably prudent burn manager met?

Questions addressing your decision to burn will be based on:

- Weather conditions
- Wind direction
- Location of neighboring roads/interstates
- How closely burn was monitored
- # people helped with fire
- Steps taken to contain the fire

<u>MS Prescribed Burning Act (1992)</u>

Miss Code Ann. §§49-19-301 through 49-19-307

- Prescribed burning is a landowner property **<u>right</u>**
- Prescribed burning benefits society.
- Promotes the use of prescribed burning for ecological, silvicultural, and wildlife management purposes.
- MS Forestry Comm has the authority to regulate burning activities on forestland in MS.
- It's purpose is to <u>authorize and promote</u> continued use of prescribed fire.
- Stops short of providing adequate protection from liability.

Minimum Requirements of Liability Protection

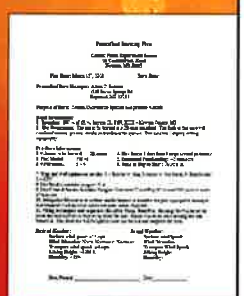
- Four Mandatory Requirements:
  - Must have a Certified Prescribed Burn Manager on site
  - Must have a notarized burn plan (at least 1 day prior to burn)
  - Must have a permit from the MFC for the day of the burn
  - Must be in the public interest and not constitute a nuisance

What is a Burn Plan?

- Written plan stating how, what, when, where, and why for burning
  - Site specific
  - Scout site and surrounding area
    - Know terrain, fuels, smoke sensitive areas
- Include burning techniques to be used
- Notarized at least one day prior to burn
- ***Legally binding once notarized***

Why do you need a burn plan?

- **The law says you do!**
- It makes you plan for the burn ahead of time
- Important for smoke management
  - If you light a fire, where ever the smoke goes, it is your (or your burning contractor's) responsibility.



The MFC will issue a permit when:

- MS Forestry Commission Central Dispatch
  - 1-833-MFC-FIRE (1-833-832-3473
- The proper environmental conditions are present for adequate smoke dispersal
- There are no burn bans in place for the county in which you want to burn.

What does "…be in the public interest." mean?

- Fuel Reduction
- Improve Access
- Site Preparation
- Competition Control
- Wildlife Habitat

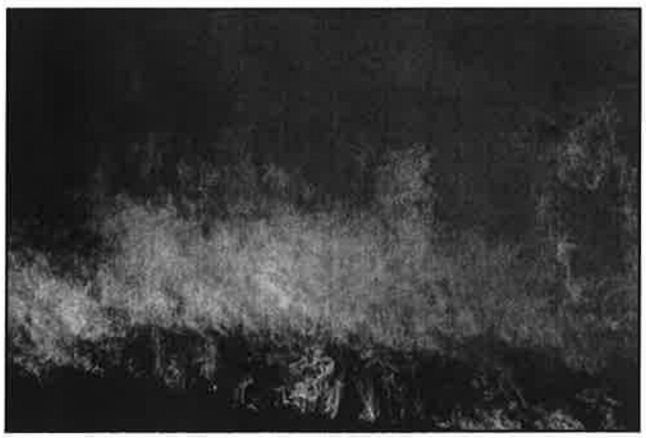
- Does not mean—I like to burn and it's pretty, so I'm gonna go torch it up………….

1992 Mississippi Prescribed Burning Act

- **Liability**
  - Simple Negligence: Damages and up to $150 fine
  - Gross Negligence: Damages, up to $500 fine, and jail time
  - **It's up to a jury to ultimately decide on negligence!!!**
- **Acts of a reasonable prudent person**
- **Responsibility of the burner**

Safety Considerations for Prescribed Fire

Brady Self
Northwest Mississippi Extension Forestry, Grenada
662-226-6000 or brady.self@msstate.edu



- Fatalities have occurred on prescribed burns and during mop up operations

Personal Safety

- **All fire is inherently dangerous, period.**
- We are going to look at items of Personal Protective Equipment (PPE), safety principles, hand tool and personal health safety.

Personal Safety - PPE

- Most entities that burn have policy that identifies minimum PPE requirements
  - Hard hat
  - Eye protection (goggles/shield) (dust/smoke/brush/ash/etc.)
  - Bandanna/dust mask
  - Boots (leather)
  - Fire shirt/pants (e.g. Nomex, heavy cotton, etc.)
  - Gloves (leather)
  - Other as needed (radio, canteen, hearing protection, saw chaps, compass, respirator, etc.

Personal Safety - Smoke Inhalation/Carbon Monoxide Exposure

- Downwind side of fire...
  - Time spent in this zone should be minimized
  - Dusk mask/bandanna/respirator
  - Rotate personnel
  - The edge is your friend...
  - Severe exposure = EMS
- CO exposure isn't typically problematic
  - Headache, dizziness, fainting, red skin color, weakness, nausea

Personal Safety - Burns

- WEAR YOUR PPE!!!
- Extra caution when using ignition sources
- First aid equipment and training
- Access to EMS

Personal Safety - Hazzard Awareness

- Situational awareness/pay attention
  - May need a designated "spotter"
  - Dangers from above (snags/limbs)
  - Poisonous plants/venomous animals
  - Terrain (holes/mud/rocks/debris)
  - Weather (wind/lightning)
  - Manmade items
    - Equipment/ditches/fences/power lines

Personal Safety - Heat Stress

- Maintaining proper body temperature can be challenging
  - Maintain physical fitness
  - Stay away from alcohol and lack of sleep
  - Acclimate (plenty of Vitamin C)
  - Set sensible pace and take breaks
  - Drink plenty of fluids
    - Before, during, and after burning

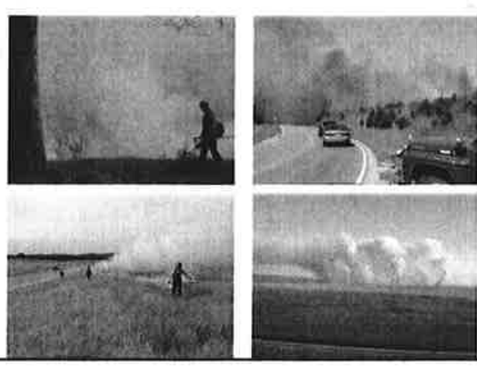
Environmental Safety - Smoke Management

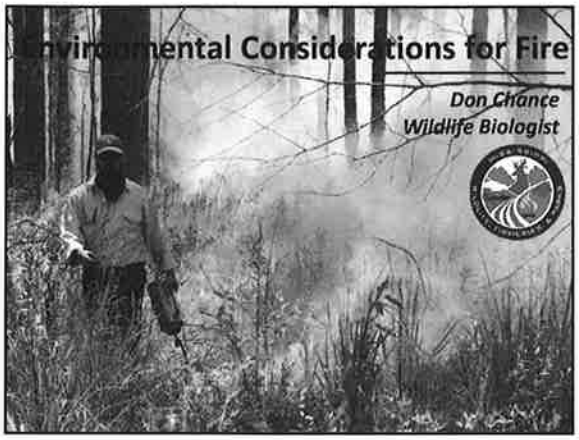
- Smoke management is the primary reason a permit is necessary!!!
  - Traffic hazards
  - Public nuisances
- If you put smoke in the air, wherever it goes, it is your responsibility

Smoke Management

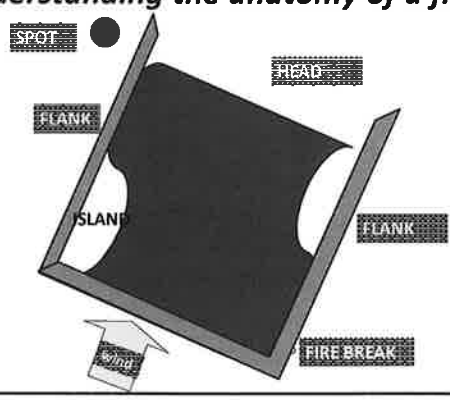
- Smoke Sensitive
  - Any area where human health, visibility, or welfare could be adversely impacted by smoke:
    - Hospitals, airports, schools, roadways, populated areas, elderly, chicken farms, etc.
    - Avoid dropping smoke here if possible
    - Disperse/dilute smoke – finish by mid afternoon, wind
    - Reduce emissions – backing fires
- Smoke Critical
  - Smoke sensitive areas in close proximity to burn
    - Depends on a variety of factors

Proper Smoke Dispersal





Understanding the anatomy of a fire



The Fire Triangle

HEAT

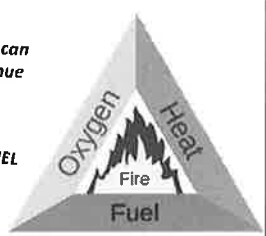
- *Without sufficient HEAT a fire can not begin and it can not continue*

FUEL

- *A fire can not exist without FUEL*

OXYGEN

- *Without sufficient OXYGEN a fire can not begin and it can not continue*



The Fire Environment

The surrounding conditions, influences, and modifying forces that determine fire behavior

Fuels

FUEL is all plant material that can be ignited by fire

Fuel characteristics strongly influence fire behavior

Types of FUELS

Dead fuel – moisture content controlled by environment

Live fuel – moisture content controlled by environment and other variables

Dead Fuels

TIME LAG & SIZE

- 1 HOUR (< ¼" Dia.)
- 10 HOUR (¼" – 1" Dia.)
- 100 HOUR (1" – 3" Dia.)
- 1,000 HOUR (> 3" Dia.)

Small diameter fuels can change rapidly in response to weather changes, while larger diameter fuels are slower to respond.
forecasts.

Live Fuels

FUEL MOISTURE
-Most important characteristic affecting fire behavior as it determines how much fuel is available for burning

HEAT SINK vs. HEAT SOURCE
-Live fuels (green fuels) can serve as a heat sink to slow down fires
-In times of drought live fuel that would otherwise not burn becomes a fuel source

BE AWARE OF FLASH FUELS
-Some fuels have a chemical composition that makes them highly flammable

Fuel characteristics

Fuel Loading

Fuel Size and Shape

Fuel Arrangement

Compactness

Horizontal Continuity

Vertical Arrangement

Fuel Chemistry

Fuel Moisture

Other factors affecting fuels

Fuel model - forests vs. grasslands vs. logging slash

Previous fire history
- Time since last burn
- Fire frequency
- Intensity
- Season of Burn

Site productivity

Other management activities
- Mowing
- Herbicides

FIRE WEATHER

IMPORTANT FIRE WEATHER

Temperature

Atmospheric moisture

- Precipitation
- Relative humidity
- Fog

Wind

Stability

Temperature

- -A basic weather element that influences other elements
- -Varies heavily in time and space based on heating and cooling of earths surface and the atmosphere
- -Burning when temperatures exceed 70°F has been shown to mortality in woody and non-woody vegetation including mature overstory trees

Atmospheric moisture

- -Direct effects on the **flammability** of forest fuels
- -Indirect effects on all other aspects of fire behavior

SOURCES OF MOISTURE

- -Precipitation – time since precipitation is important
- -Relative humidity – critical
- -Fog – important for smoke

Wind

-Increases oxygen supply

-Aids fire spread by carrying flames/embers to new fuels

-Direction of fire spread is determined by wind

-Critical to fire planning

Sustained wind speed – measured 20 ft off ground

Gusts - burn permits and plans based on sustained wind, but gusts are critical

Stability

-Resistance to vertical motion

-Warm air rises

-High stability may cause **inversions** (pockets of cool air close to the ground)

-Unstable atmospheric conditions result in higher **mixing heights** (where convection causes smoke to mix with air rapidly)

Stability

-affects dispersion of smoke

-high instability makes fire behavior unpredictable

-high stability increases risk of smoke related problems

<u>MFC burn permit standards</u>:

Transport wind ≥ 3 meters/sec

Mixing height ≥ 890 meters

OR

Transport wind ≥ 3.5 meters/sec

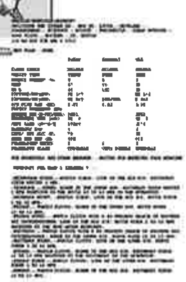
Mixing height ≥ 500 meters

Topography

-SLOPE – affects fire frequency by changing flame angle, as slope steepness increases so does the rate of spread

-ASPECT- affects fire behavior due to differences in wind/ temp, daytime upslope winds are stronger on south and west slopes

Where to find weather information



NOAA Fire Weather

Mississippi Forestry Commission

On-site measurements
- Kestrel weather station
- 10-hour fuel moisture sticks
- Sling psycrometer
- Anemometer

Using fire behavior and weather

When is the best time to burn?

Controlling woody growth
- 10-hour FM = 9-10%
- KBDI = 500-700
- RH = 20 – 35%
- temperature = 50 – 100

Late vs. early growing-season?
- plant physiology

Maintenance burning – December – March
stability, FM, Temp…RH

Using fire behavior and weather

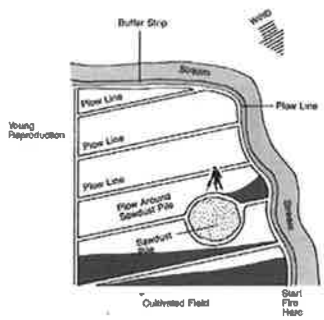
Dormant season
- "maintenance" burning
- fuel reduction
- increasing grass density
- site preparation

Growing season
- reduce woody plants
- reduce grass density
- increase forb/legume

Firing techniques?

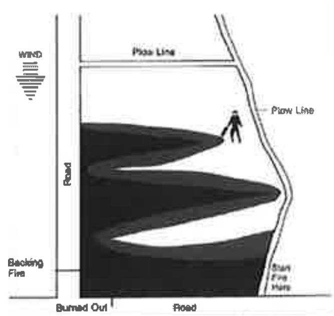
Firing techniques

Backing Fire



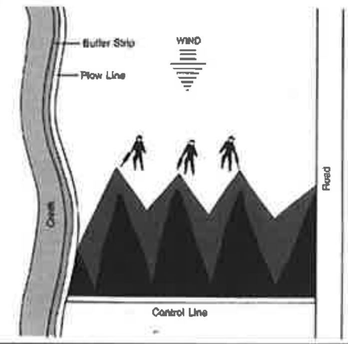
Firing techniques

Strip-head fire



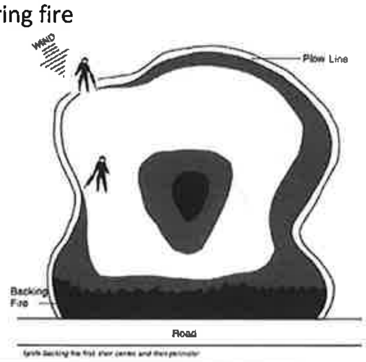
Firing techniques

Flanking fire



Firing techniques

Center ring fire



Questions?

www.mdwfp.com/privatelands

Creating Burn Plans

Brady Self
Northwest Mississippi Extension Forestry, Grenada
662-226-6000 or brady.self@msstate.edu

Reasons to Create a Plan

- Planning has always been important, but is essential in today's efforts
- Planning is an opportunity to get in front of potential problems
- Once ignition occurs... too late to start thinking of overlooked elements or things that may go wrong

Starting the Planning Process

- As a part of overall land management, inventory properties for criteria such as:
  - Fuel loading
  - Burn history
  - Known problem areas
  - Desired return interval
  - Etc.
- Divide large areas into one-day burning blocks

Prescriptions (Plans) for Individual Burns

- A burn prescription/burn plan is a written document defining the range of conditions of temperature, humidity, wind direction and speed, fuel moisture, atmospheric stability, soil moisture, and geographical area under which a fire will be **ignited** and/or **allowed to burn** in order to obtain stated objectives.

Prescriptions (Plans) for Individual Burns

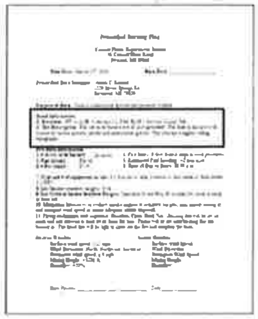
- Necessary for **EVERY BURN**
- 1992 MS Prescribed Burning Act
  - Must have prescription notarized at least 1 day prior to burn ignition (legally binding)
- No blanket prescription exists – all will differ
- Site specific

Prescriptions (Plans) for Individual Burns

- Purpose and Objectives
  - Purpose = Silvicultural, site preparation, forage enhancement, wildlife purposed, fuel reduction, control of invasives, etc.
  - Objective = measurable
    - Ex. Reduction of fuel = desired % reduction and/or estimate of fuel loading before/after burn

Prescriptions (Plans) for Individual Burns

- Burn unit description:
  - Location (legal description/lat-long)
  - Size
  - Plant Communities
    - Overstory/understory (detailed)
  - Fuels
    - Target fuels = type, loading, continuity, and arrangement
    - Non-target fuels = everything else, duff, ladder fuels, etc.
  - Topography
  - Special features



Prescriptions (Plans) for Individual Burns

- Map of burn unit
  - Well defined boundaries
  - Access shown
    - Remember items like bridge weight limits
  - Designated collection/meeting spots
  - Firelane/breaks
    - Plowed, trails, creeks, etc.
  - Structures needing protection
    - Bridges, deer stands, houses, etc.

Prescriptions (Plans) for Individual Burns

- Weather factors:
  - Pre-burn and post-burn
  - Conditions suitable for burning
    - Wind direction and speed
    - Relative humidity range
- Fuel conditions
  - Estimated fuel loading, arrangement, particle size (hour system), continuity, density, exposure time, etc.

Fuels

- Time Lag
  - 1hr: <1/4 inch diameter
  - 10hr: 1/4-1 inch diameter
  - 100hr: 1-3 inches diameter
  - 1000hr: >3 inches diameter

Prescriptions (Plans) for Individual Burns

- Season and time of day:
  - Seasonal timing guided by goals and is influenced by weather
    - Strong correlation to safety
  - Time of ignition and burn-out required
- Equipment and personnel
- Listing of smoke sensitive and critical areas
- Mitigation measures to reduce smoke impact

Prescriptions (Plans) for Individual Burns

- Firing technique and sequence
  - Can be a Firing Plan section of the overall burn plan completely
- Contingencies, mop up plans, and expired fire declaration
- Miscellaneous
  - Plan for informing local fire and law enforcement departments


Questions?

The Risks and Rewards of Prescribed Fire

John L. Willis
Assistant Professor
Department of Forestry
Mississippi State University

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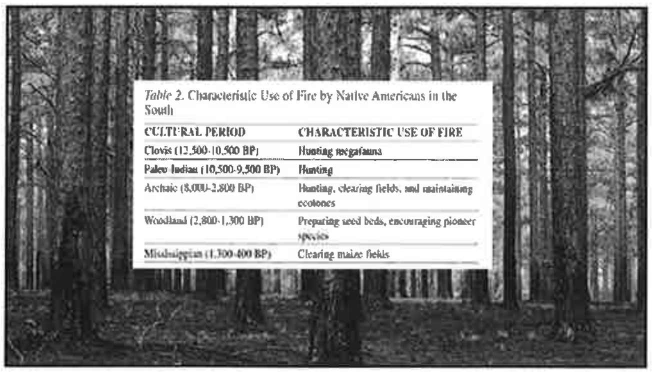


Table 2. Characteristic Use of Fire by Native Americans in the South

CULTURAL PERIOD	CHARACTERISTIC USE OF FIRE
Clovis (12,500-10,500 BP)	Hunting megafauna
Paleo Indian (10,500-9,500 BP)	Hunting
Archaic (8,000-2,800 BP)	Hunting, clearing fields, and maintaining ecotones
Woodland (2,800-1,300 BP)	Preparing seed beds, encouraging pioneer species
Mississippian (1,300-400 BP)	Clearing maize fields

Artificial Regeneration

- Prescribed fire is the most cost-effective tool for reducing slash loads
- Artificial regeneration benefits
- Planting access
- Planting quality
- Spacing considerations (volunteer seedlings)

Natural Regeneration

- Prescribed burning aids natural regeneration by creating seedling establishment sites
- Mineral soil access and competition

Wildlife Considerations

-Prescribed fire is an excellent tool for maintaining wildlife habitat

-Increases light availability at the forest floor and stimulates the soil seed bank

-Herbaceous vegetation advantage

-Access to forage and nutritional value of forage Improves

Fuel Reduction

- Fire intensity is derived from the fuel available to burn
- Frequent burning to reduce fuel loads diminishes the risk of a damaging wildfire
- The southeast is different from the west

Aesthetic Purposes

More Reasons to Burn

Fire and Risk

- Risk can be minimized with appropriate planning, but risk can never be completely avoided with prescribed fire.
- Public safety concerns and liability are paramount
- Stand level risk

Fire Mode of Death

-Fire kills living tissue once temperature reaches 60 C 140 F

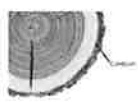
-Cambium and roots are the primary concerns in prescribed fire

Species Effects

-Bark helps insulate the cambium from burning

-Fire adapted species tend to have thicker bark compared to species less adapted to fire

-Fire adapted does not mean impervious



Age

-Most species will gain bark thickness as they age

-Most trees gain resistance to fire as they age

-The ability to alter species with prescribed fire declines with stand age

Regeneration (Seeds)

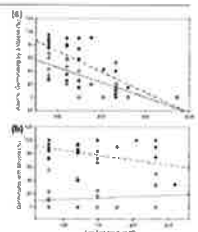
-Given their size, seeds are the most vulnerable to fire

-Risk varies with seed production frequency

-With the exception of longleaf pine, seed losses are not major concern in naturally regenerating pine

-Burning after an oak mast year can delay regeneration 3-10 years

Fig. 3. Regression of (a) proportion of acorns germinating, and (b) proportion of germinants with shoots on prescribed fire temperature on northern red oak (solid circle, dotted line) and white oak (hollow diamond, solid line) for acorns placed on the leaf litter surface at time of burn.



(Greenburg et al. 2012)

Regeneration (Pine)

Newly established loblolly pine seedlings do not tolerate fire (High risk)

-Grass stage longleaf > 1 year are resistant to fire

-Fire promotes longleaf

- Shortleaf pine seedlings can sprout up to 7 years
- Fire promotes shortleaf

Regeneration Hardwoods

-A high percentage of hardwood seedlings will sprout after fire

-Species differ in their sprouting vigor

-Oaks tend to sprout with more vigor than most competing species

-Risk is low for most hardwood species

Advance Regeneration

-Saplings of both pine and hardwood are Vulnerable to prescribed fire

-4 inch threshold

-Pines will not sprout

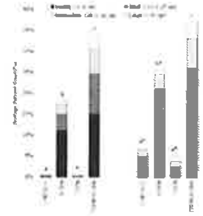
-Hardwoods will sprout, but you will lose time and potentially competitive position

-Herbivory concerns

Sapling Mortality

Fig. 3. Cumulative mortality of trees in upland oak woodland restoration sites of the Missouri Ozarks. Measurements were made in 2003 and 2006 following prescribed burn treatments. 1Letters indicate significant differences between each treatment 2Asteriks indicate significant differences from 2003 to 2006 within each treatment

(Kinkead et al. 2017)



Overstory Damage

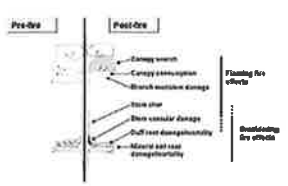
-Thick bark provides most species' with a degree of fire resistance by the time they reach the overstory

-However, situations can arise that increase the odds of damage to overstory trees

Organic Layer Buildup

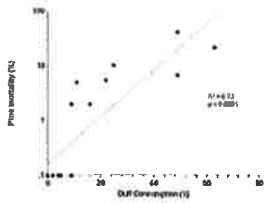
(Varner et al. 2007)

Problematic Scenarios: Organic Layer Buildup



(Varner et al. 2007)

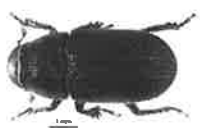
Pine Mortality and Organic Layer Burning



(Varner et al. 2007)

Insect Damage

- Resin is highly flammable
- Create hot spots that can kill neighboring trees
- Avoid burning in stands heavily damaged by insect



Dangerous Fuels

Cogongrass

Yaupon

Overstory Damage

Red Oak Value Loss

-Oftentimes, volume loss isn't responsible for the loss in value

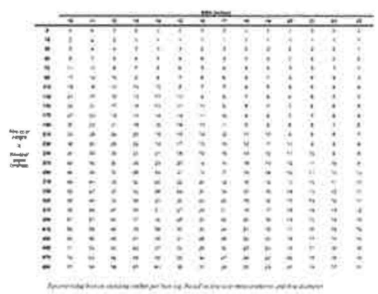
-Value loss comes from a downgrade in log quality

-Increasing fire scar depth and height leads to greater volume loss

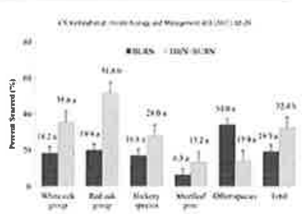
-Value loss is magnified in smaller trees

-Harvesting within 5 years of damage can help limit damage

(Marshall et al. 2014)

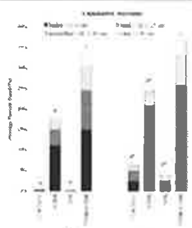


Burning After Thinning



(Kinkead et al. 2017)

Burning After Thinning



(Kinkead et al. 2017)

Weighing The Risks of Prescribed Burning

- Rank stand management objectives
- Examine the age structure and species composition of the stand
- Take into consideration all of the positive and negative effects that could happen within the stand
- Recognize risk mitigating options
- Fire is an excellent tool, but it isn't the only tool

Questions

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Supporting Literature

Prescribed Burning in Southern Pine Forests:
Fire Ecology, Techniques, and Uses for Wildlife Management

Prescribed burning is an important wildlife management tool used in our Southern pine forests. Because these forests regularly experienced burns in the past, vegetation and wildlife have adapted to fire and actually benefit from the effects of prescribed burning. Unfortunately, because of new pine management techniques and concerns about fire, many landowners are reluctant to use fire on their property. If done correctly, though, prescribed fire can be an effective, safe, and affordable management tool.

Benefits to Wildlife

If used properly, fire is one of the most beneficial and cost-effective wildlife habitat management tools available. For example, burning every 2 years maintains early stages of plant succession that bobwhite quail require. Fire reduces leaves/needles (litter) on the forest floor and exposes soil so bobwhites can easily find seeds. It creates open foraging and travel areas for hens with young chicks, and it encourages plants that provide food (insects and seeds) and cover for bobwhite. Fire also acts as fertilizer by removing vegetation and litter, returning many nutrients to the soil.

Burning is often conducted in late winter, although burning in other seasons may be conducted to accomplish specific habitat management objectives. To be most effective at providing a variety of plant types, divide the burnable acreage into three or four sections and burn one section each year. Having burned and unburned areas next to one another ensures food and cover is always available and in close proximity.

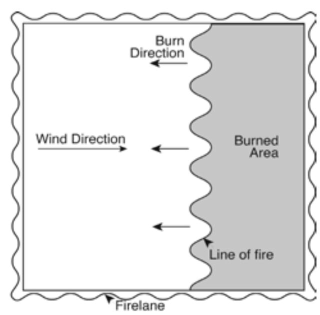
Wild turkey gain many of the same benefits from fire that bobwhites do. For turkey, it is best to burn before April to avoid nesting season, but burn less frequently (every 3 to 5 years) if turkey habitat is a specific objective. Fire creates and maintains forest openings in quality brood-rearing habitat 1 to 2 years after burning, and provides great nesting cover 3 to 4 years after burning.

Burning every 3 to 5 years increases white-tailed deer forage production and quality. It also maintains forage close to the ground, well within a deer's reach. Good fawning cover is also produced 3 to 5 years following a burn. Burning top-kills hardwood brush and promotes sprouting of browse species. Winter burns are normally best for deer management.

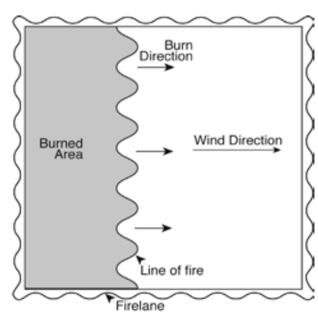
Some of the species that suffer from the declining use of fire include bobwhite quail, wild turkey, white-tailed deer, gopher tortoise, and red-cockaded woodpecker. Populations of other birds, mammals, and reptiles, as well as amphibians, insects, and plants, also have declined in the absence of fire.

Important Prescribed Burn Techniques

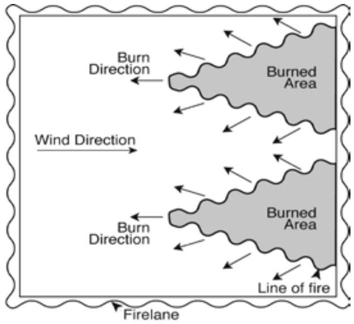
Back fire. Back fires are set directly against the wind. This is one of the safest methods of prescribed burning and is recommended for beginning wildlife managers or where there are fire hazards, such as adjacent lands with high-danger fuels. Wind speed should be no more than 6 to 10 mph.



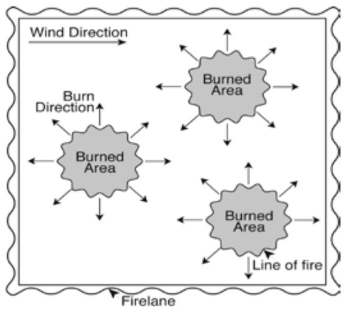
Head fire. Head fires are set with the wind direction and should only be used by experienced professionals under ideal fuel conditions. Head fires burn quickly, have a taller flame, and can kill even large pines if used improperly; however, head fires are very effective at maintaining early successional wildlife habitat. A strip head fire (lighting a head fire in small strips) can be effective while keeping the fire from becoming too hot and damaging pine trees.



Flank fire. Flank fires are often used when the fuel is relatively light. These fires are set by an individual or individuals walking into the wind and are relatively safe.



Spot fire. Ideally, spot fires are set at equidistant locations throughout the forest. These fires gradually expand until they join.



Expense and Equipment

Prescribed fire is one of the most economical wildlife management tools available. Burning costs vary with tract size, application method, manpower needed, equipment used, and timber/fuel conditions. Never burn without proper equipment to stop a fire if it were to escape a fire lane (for example, be sure to have a bulldozer equipped with a fire plow or a tractor and disk). Other required equipment includes drip torches, fuel (a 3:1 mix of diesel and gasoline), fire rakes, flappers, and water.

Consulting foresters, the Mississippi Forestry Commission (MFC), and other prescribed burn contractors provide this service. If you choose to hire someone for prescribed burning, costs average $25–30 per acre.

Prescribed Fire Landowner Liability

In Mississippi, landowners have the right to burn their property according to the Mississippi Prescribed Burning Act of 1992. However, there are a few requirements to minimize liability associated with prescribed burning:

1. A certified prescribed burn manager must be on-site to supervise the burn.
2. A written burn plan must be prepared and notarized before the burn day. If conditions do not meet parameters set forth in the burn plan, do not burn even if a burning permit is issued.
3. A burning permit must be obtained from the MFC on the burn day. Contact your local MFC county or regional office to receive the permit. If conditions to burn are not favorable, the burn permit will not be granted.
4. The burn must be in the public interest (i.e., timber or wildlife habitat improvement).

Steps to Conducting a Prescribed Burn on Your Property

- Become a certified prescribed burn manager. Landowners can become certified by completing a course offered through Mississippi State University and the MFC.
- Develop a burn plan for the area to be burned that includes desired ranges of wind speed and direction, temperature, humidity, and burning techniques to be used. Have the plan notarized at least 1 day before burning.
- Arrange for appropriate equipment and personnel to be present at the burn.
- Create fire lanes around the tract at least 2 weeks before the burn. Fire lanes should be cleared of all debris. Often, landowners maintain fire lanes with perennial green forages such as white clover.
- Notify your neighbors of your plan.
- On the burn day, recheck fire lanes, and recondition them if necessary.
- On the burn day, get a burn permit from the MFC.
- Conduct the burn according to your burn plan and burn permit (a permit is valid only for the day it is issued).
- While burning and after the burn, check all boundaries for escaped fire and to make sure all fires are extinguished when the burn is complete.

Publication 2283 (POD-03-16)

By **Bronson Strickland**, Associate Extension Professor, Wildlife, Fisheries, & Aquaculture; and Scott Edwards and Rick Hamrick, Wildlife Biologists, Prescribed Burn Managers, Mississippi Department of Wildlife, Fisheries, & Parks.

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When Will a Prescribed Burn Help My Pine Stand?

Fire is part of a healthy Southern pine forest. Fire can enhance the productivity of pine forests, but it can also cause injury, poor growth, and death of desirable trees.

Prescribed burning is the deliberate use of fire under ideal conditions to achieve forest management objectives. Since fire can both harm and benefit forests, landowners may wonder when prescribed burning is "right" for their pine stands. You should consider several important factors in determining when or if prescribed burning will help you manage your pine stands.

These factors include—

- your stand management objectives;
- tree diameter, height, and spacing;
- the amount of pine litter, brush, and other fuels beneath the pines; and
- the time of year to use fire to accomplish your objectives.

We recommend you seek competent professional forestry advice about using prescribed burning to reduce damage and potential liability.

Management Objectives

You will usually have more than one management objective for your pine stands. The main one may be timber production, but you may also wish to manage your stands for wildlife benefits and natural beauty. Prescribed burning can help you reach all of these management objectives. It can control competing vegetation in pine stands that would otherwise reduce the growth of the desired trees as well as reduce the risk of destructive wildfires.

Prescribed burning is the deliberate use of fire under ideal conditions to achieve forest management objectives.

Wildlife species such as turkey, deer, and quail benefit from the plant growth stimulated by prescribed burns. Research has shown that both quantity and quality of understory food plants for these and other animals are improved through a series of prescribed burns. Also, the edge between burned and unburned stands increases the variety of wildlife habitat on a landowner's property.

Prescribed burning can improve the appearance of a stand by increasing visibility and stimulating the production of flowering plants in the understory. Improved access through the stand also improves recreational opportunities such as hiking and birding. Easier access created by prescribed burns will make future thinnings and harvest sales more attractive to timber buyers and loggers.

Condition of the Pine Stand

Many landowners ask, "How old should my pine trees be before I can use a prescribed burn?" Other factors are more important than the age of your trees. These factors include tree diameters, tree heights, and the spacing of the trees.

Tree Diameter

Diameter at Breast Height (DBH) is the diameter of a tree, outside the bark, at a point 4½ feet above the ground. The diameter of pines from ground level to DBH indicates the tree's resistance to damage from fire. Larger diameter trees have a thicker layer of bark that insulates the tree from the heat of the fire. Pines with a DBH of 3 to 5 inches can usually withstand a low-intensity, winter season prescribed burn. Pines with 8, 10, and 12 inches DBH can tolerate higher intensity fires in different burning seasons. Trees with a DBH less than 3 inches can be damaged by fire and should not be burned.

Tree Height

As trees grow taller, they shed their lower branches. This creates a gap between a fire on the forest floor and the tender needles and shoots on the living branches that can be damaged by the fire. As the distance between the live pine branches and the forest floor increases, so does the tree's tolerance to the effects of prescribed burning. If a stand contains live branches below 6 to 8 feet in height, a prescribed burn should be postponed for at least 2 years.

Tree Spacing

The spacing of pine trees impacts how quickly the lower branches of each tree will be shed. Closely spaced pines shed their lower branches sooner than pines planted farther apart. These branches contribute to the fuel on the forest floor. In addition, the crowns of closely spaced pine trees can trap heat from a prescribed burn beneath the live branches. This heat can injure or kill pine needles in the crowns and weaken the trees.

Although a closely spaced pine stand may appear to have a thick carpet of pine needles and twigs on the forest floor, not all of this fuel may burn at any given time. Weather conditions before and during the fire affect how much of the fuel is actually burned. Also, the closely spaced pine trees will shed their lower branches and needles earlier in life, thus increasing the amount of fuel on the forest floor. The close spacing inhibits fire by trapping moisture in the pine litter and reducing the amount of brush or other plants that can grow in the understory.

A closely spaced pine stand with dead branches close to the ground that are draped with dead pine needles is a special concern. These dead needles are dry and extremely volatile. If you do not burn properly, these draped fuels can carry a fire from the forest floor into the tree crowns, causing severe injury and perhaps killing the trees.

These are the minimum general conditions to consider before conducting a prescribed burn in your pine stand:

- An average DBH of 6 inches or greater
- A minimum distance of 15 feet to the lowest live branch
- Adequate canopy gaps to allow heat to escape

Time of Year

It is important to plan the first prescribed burn of a pine stand during the winter burning season. Cool air temperatures and more predictable winds create more favorable fuel moisture conditions for a low-intensity fire that should cause little damage to the pine trees. Prescribed burns conducted later or after earlier burns can be scheduled at other seasons to produce higher-intensity burns to meet different objectives. For example, the best time to burn to control understory brush and vegetation is in late spring or early summer. Small understory hardwood species are more easily killed by a prescribed burn at this time.

Conclusion

Fire can be beneficial or damaging to pine forests. Prescribed burning is a very useful tool in pine management, but only when applied carefully and by skilled professionals. Other aspects of prescribed burning, such as cost, availability, firing techniques, and other details have not been discussed in this publication. Seek the advice of local foresters if you are considering prescribed burning. Professional foresters can help you plan a safe burn—for both you and your pine stands.

Further Reading

Managing the Family Forest in Mississippi, Department of Forestry, Mississippi State University.

"Prescribed Burning in Southern Pine Forest," Mississippi State University Extension Service Publication 2283.

Legal Environment for Prescribed Burning in Mississippi, Forest and Wildlife Research Center Mississippi State University Research Bulletin.

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Legal Environment for forestry Prescribed Burning IN MISSISSIPPI

FOREST AND WILDLIFE RESEARCH CENTER
Mississippi State University
Research Bulletin

The Forest and Wildlife Research Center at Mississippi State University was established by the Mississippi Legislature with the passage of the Renewable Natural Resources Research Act of 1994. The mission of the Center is to conduct research and technical assistance programs relevant to the efficient management and utilization of the forest, wildlife, and fisheries of the state and region, and the protection and enhancement of the natural environment associated with these resources. FWRC scientists conduct research in laboratories and forests administered by the University and cooperating agencies and industries throughout the country. Research results are made available to potential users through the University's educational program and through Center publications such as this, which are directed as appropriate to forest landowners and managers, manufacturers and users of forest products, leaders of government and industry, the scientific community, and the general public. Dr. George M. Hopper is director of the Forest and Wildlife Research Center.

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Legal Environment for Forestry Prescribed Burning in Mississippi

by
Changyou Sun and Andrew J. Londo

Forest and Wildlife Research Center
Mississippi State University

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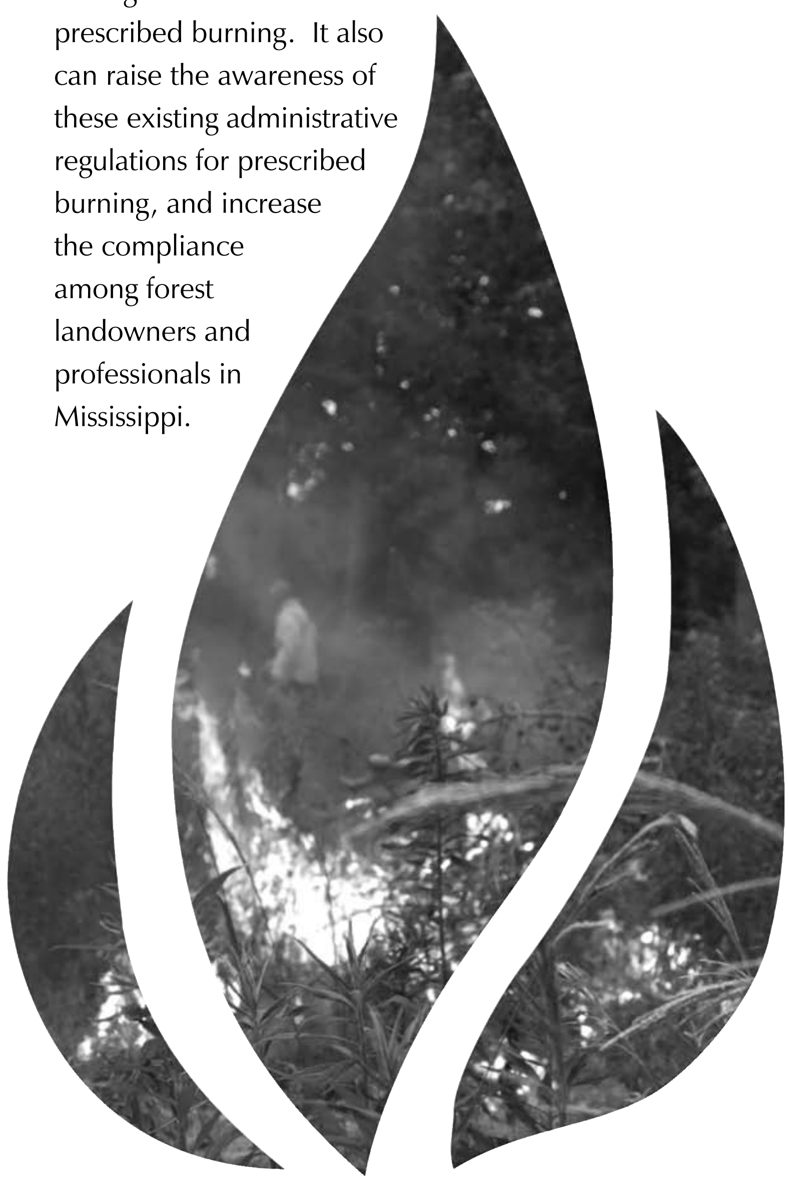
INTRODUCTION

For the 19.8 million acres of forest land in Mississippi, prescribed burning has been one of the major management tools available to forest landowners. Benefits associated with prescribed burning have long been recognized in the forestry community. These include vegetation control, wildlife habitat improvement, site preparation for regeneration, disease control, fuel reduction, and wildfire prevention (McNabb 2001). Yet, even with these advantages, the use of prescribed burning has become more challenging in recent years. To a large degree, this is due to the increasing concerns of landowners over liability exposure and legal consequences from smoke and escaped fires.

The legal environment of prescribed burning on forest land is composed of various laws. In general, laws come from four sources: common law, statutory law, administrative law, and Constitutional law (Eshee et al. 2005). Common law is rooted in the common practices of people. As a body of law derived from judicial decisions, common law also is referred to as judge-made law. Statutes are created by legislative bodies (i.e., the U.S. Congress and state legislatures). While common law has greater flexibility in dealing with specific factual circumstances, statutory law usually provide more specific treatments for a given issue. Administrative law refers to the vast body of law promulgated by various administrative agencies which operate much of our government on a daily basis. Constitutions are the basis of the government framework and the cornerstone of the legal system. For prescribed burning, common law has been the dominant source of law for many years while Constitutional law has rarely been the center. Statutory laws and associated administrative regulations have become gradually more important for prescribed burning on forest land in the South since 1990.

The purpose of this publication is to review relevant laws related to the use of prescribed burning on forest land in Mississippi. These laws are summarized under three categories: common law, statutory law, and administrative law. Several court cases are reviewed to elaborate the legal principles that have been required by the courts in Mississippi. This is followed by the examination of statutory laws related to prescribed burning in Mississippi. Emphasis will be placed on the Mississippi Prescribed Burning Act of 1992, a statutory law specifically enacted for prescribed fire. Administrative laws and regulations related to this Act have been promulgated by the Mississippi Forestry Commission and they also will be analyzed. At the end, useful linkages related to the legal environment of prescribed burning are presented. This publication will be helpful for forest landowners and managers in Mississippi to understand the legal environment of prescribed burning. It also can raise the awareness of these existing administrative regulations for prescribed burning, and increase the compliance among forest landowners and professionals in Mississippi.



COMMON LAW FOR PRESCRIBED BURNING IN MISSISSIPPI

Two aspects of common law are related to prescribed burning on forest land—property law and tort law. Property law deals with the right of owners to use their land as they see fit in relationship to others in society (Eshee et al. 2005). For forest landowners, it has been long recognized and rooted in common law that they have the right to set fire intentionally on their land for a legitimate management purpose, such as burning brush. In contrast, tort law pertains to civil harms occurring to people or properties, and it covers all civil wrongdoing except breach of contract. Prescribed fire may spread onto someone's land, and cause personal injuries or property damages, or both. Considering property law and tort law together for forest landowners, the balance between property rights and tort protection specifies the way of using prescribed burning on forest land.

When prescribed burning results in personal injury or property loss, tort law can provide the remedy to resolve the dispute between the injurer (i.e., landowner or burner) and the victim. Among the various tort rules, discussions of the common law for prescribed burning usually concentrate on negligence tort rules. Several cases in Mississippi have elaborated these negligence rules well. In addition, forest landowners may also be held vicariously liable for the negligent acts of their employees or independent contractors. Vicarious liability and the relevant cases are also examined below.

Negligence Tort Rules and Mississippi Negligence Cases

Negligence rules permit a defense that the accident occurred despite the fact that the defendant satisfied all applicable standards of care. Thus, they may allow the defendant to reduce or even avoid liability (Eshee et al. 2005). Proof of negligence requires four elements: duty, breach of a duty (i.e., fault), causation, and loss. Duty is the obligation that each person in society owes others to act in a manner which is not negligent toward them. Different activities and situations dictate special duties. When the duty has been established, the next determination is whether or not the defendant has breached the duty. Should the conduct of a person not achieve the standard of care demanded by society and decided by the court, then the duty has been breached. Furthermore, there should be a close causal connection between the breach of duty by the defendant and the loss sustained by the victim. Finally, the plaintiff must prove that actual loss has been suffered.

The number of Mississippi cases involving prescribed burning is small. However, the few cases that have been decided offer good guidance (Eshee and Savelle 1993). In the case of *Wofford v. Johnson* (1964), Holliday, an employee of the defendant Johnson, pushed up several piles of brush with a bulldozer and set one pile on fire at about 3:00 p.m. on March 23, 1964. The pile was approximately thirty feet in diameter and about one hundred and fifty-two feet from the woods on Johnson's land. The burning pile and woods were separated by a stretch of green rye grass. The fire was not checked that night. The next morning Holliday observed Johnson's woods burning but made no effort to control the fire. Johnson was informed of the fire but made no effort to control it. The fire spread to Wofford's property where it burned over six hundred and eighty-two acres causing extensive damage. The weather conditions for that time of the year were very dry.

The court held that when a property owner or his employees set a fire on his own property for a lawful purpose, he would not be liable for damage caused by the spread of the fire to the property of another unless he was negligent in starting or controlling the fire. The court found that the measure of diligence required was ordinary care. Ordinary care was defined as such care, caution and diligence as a prudent and reasonable person would exercise under the circumstances to prevent damage to others. Such care must be used in setting the fire and in keeping it or preventing its spread. The duty of ordinary care should be commensurate with the danger reasonably to be anticipated and dependent on the circumstances in the particular case. Given these standards and facts, the court found that the landowner in this case was negligent.

In *Robinson v. Turfit* (1941), the court stated that in determining what action would be negligence, the court held that many factors had to be considered. Some of these factors included: conditions and circumstances surrounding the guarding of fire to prevent its spread, the number and magnitude of fires, the condition of the soil and the amount of litter, the state of the weather, the direction and force of the wind, and the relative situation and exposure of the property of the plaintiff. Other factors to consider would be the type of fuel in the fire, the number of fire fighters available, the experience and level of training of the fire fighters, and the type and amount of equipment available for controlling the fire.

Vicarious Liability of Landowners for Torts Committed by Burners as Employees

Forest landowners must be aware that the acts of their employees or agents may subject them to vicarious liability. Vicarious liability is the liability of one individual, without any wrongful conduct on his part, for the wrong committed by another (Eshee et al. 2005).

Under the doctrine of Respondeat Superior, an employer is liable for the negligent acts of his employee, if such negligent acts occurred while the employee was acting within the scope of his employment (Eshee and Savelle 1993, Eshee et al. 2005). An employee is a person employed to render services to an employer. The employer retains the right to control the employee in the method and way of rendering services. The essential feature of the employer/employee relationship is that the employer has the right to control the physical activities of the employee, as well as the manner of accomplishment of the employment duties. Scope of employment means the work the employee is engaged in is the type he was hired to perform during the working hours. Thus, a forest landowner, whose agents or employees are negligent in conducting prescribed burning, may be held vicariously liable for the negligent acts of his employees, if such agents or employees were acting within the scope of their employment when the negligence occurred.

Gloster Lumber Company v. Wilkerson (1918) illustrated the doctrine of Respondeat Superior and its application to prescribed burning well. In this case, the employees of Gloster Lumber Company were burning a tract of land. The fire crossed over onto the land of the plaintiff and burned over fifty acres. The employees of Gloster Lumber Company were found negligent in their control of the fire, and as a consequence the employer, Gloster Lumber Company, was held vicariously liable for the damages caused by their negligence. The negligent employees were also held liable (Eshee and Savelle 1993).

In *Gulf Oil Corp. v. Turner* (1970), the burner contracted as an independent contractor with the landowner Gulf Oil Corp. to burn 100 acres of woodland (See **Exhibit I**). However, during the burning, the foreman from Gulf Oil Corp. controlled the burner in setting the fire. As a result, the court refused to admit the contract and held that the burner was not independent of Gulf. The burner as the employee of Gulf was not responsible for the burning which produced smoke that covered a portion of the highway where an automobile accident ultimately occurred. Gulf as the landowner and employer was responsible for all the negligence and damages from the fire.

It should be noted that an employer cannot protect himself from liability by imposing safety rules on his employees or by giving his employees specific and detailed orders to proceed with their work in a careful manner (Eshee et al. 2005). The doctrine of Respondeat Superior goes beyond negligent torts. The employer may be held liable for intentional torts of the employee when the intentional torts are reasonably connected with the employment and are within the scope of employment.

Vicarious Liability of Landowners for Torts Committed by Burners as Independent Contractors

An independent contractor is different from an employee in several aspects. Although the independent contractor works for the employer, the employer has no right to control the contractor in the method, way, or mode of accomplishing and completing the work. The independent contractor contracts with the employer regarding the results to be accomplished—not regarding the manner or procedure for accomplishing and completing the work. The independent contractor is usually paid a negotiated, lump sum for the entire job, while the employee is normally paid a wage. Although the completed job must meet certain specifications, the method of performance is entirely within the discretion of the contractor. The independent contractor usually possesses a higher degree of skill or expertise than the normal employee. The independent contractor usually owns his own business and uses his own tools, while the employee generally depends on the employer to furnish these items.

The purpose for distinguishing between the employee and the independent contractor is because the doctrine of Respondeat Superior usually applies to the employee but not the independent contractor. The employer will generally not be held liable for negligent wrongs of an independent contractor unless ultra-hazardous activities are conducted. The Supreme Court of Florida in *Madison v. Midyette* (1989) held prescribed burning to be an inherently dangerous activity and ruled that the employer (i.e., the forest landowner in the case) was vicariously liable for a burning contractor's negligence. The court said that setting a fire clearly is a dangerous activity because it is inherently dangerous. To date, Mississippi courts have not defined prescribed burning as an ultra-hazardous or inherently dangerous activity.

STATUTORY LAW FOR PRESCRIBED BURNING IN MISSISSIPPI

Several statutes in Mississippi are related to the intentional use of fire for forest land management. While the Mississippi Prescribed Burning Act of 1992 was specifically enacted for prescribed burning on forest land, two other statutes are also related, as explained below.

Two existing statutes in Mississippi are closely related to prescribed burning on forest land. One deals with arson and willfully or negligently setting fires to woods, defined in Section 97-17-13 of Mississippi Code Annotated (1972 as amended). The other is about trespass by firing woods, defined in Section 95-5-25 of Mississippi Code Annotated (1972 as amended). The two statutes are listed as follows.

Section 97-17-13 Arson; willfully or negligently firing woods, marsh, meadow, etc.

"If any person willfully, maliciously, and feloniously sets on fire any woods, meadow, marsh, field or prairie, not his own, he shall be guilty of a felony and shall, upon conviction, be sentenced to the state penitentiary for not more than two (2) years nor less than one year, or fined not less than two hundred dollars ($200.00) nor more than one thousand dollars ($1,000.00), or both, in the discretion of the court.

Provided, however, if any person recklessly or with gross negligence causes fire to be communicated to any woods, meadow, marsh, field or prairie, not his own, he shall be guilty of a misdemeanor and shall, on conviction, be fined not less than twenty dollars ($20.00) nor more than five hundred dollars ($500.00), or imprisoned in the county jail not more than three (3) months, or both, in the discretion of the court."

Section 95-5-25 By firing woods

"If any person shall set on fire any lands of another, or shall wantonly, negligently, or carelessly allow any fire to get into the lands of another, he shall be liable to the person injured thereby, not only for the injury to or destruction of buildings, fences, and the like, but for the burning and injury of trees, timber, and grass, and damage to the range as well; and shall moreover be liable to a penalty of one hundred and fifty dollars in favor of the owner."

These statutes are closely related to intentional torts or gross negligence. Intentional torts like arson are similar to crimes in many aspects. Gross negligence is the lack of even slight care. The conduct of the individual falls far below the conduct of the reasonable prudent person associated with simple negligence. In other words, gross negligence is the intentional failure to perform a manifest duty in reckless disregard of the consequences affecting the life, health or property of another. One found grossly negligent in conducting his prescribed burning activities may be held liable for damages caused by his gross negligence. That person would also be subject to criminal prosecution for the same acts of gross negligence.

Both of these statutes have their origination from codes enacted over 100 years ago. The primary purposes of these statutes are to protect forests and private property. In contrast, prescribed burning on forest land is intentional use of fires with forest land management as the legitimate purpose. Thus, the two statutes may not apply to prescribed burning on forest land in many situations. Nevertheless, they are related to the use of fires on forest land and often declared in courts by plaintiffs.

Mississippi Prescribed Burning Act of 1992

Because of the constraint brought by existing statutes and the demand of prescribed burning as a management tool on forest land, a number of states in the United States have passed Prescribed Burning Acts since 1990 (Sun 2006). The Mississippi legislature did so during the 1992 Session and the law has been effective since March 1, 1993. As shown in **Exhibit II**, this Act was entitled the "Mississippi Prescribed Burning Act" (Section 49-19-301 to 307 of Mississippi Code Annotated, 1972 as amended). It codifies prescribed burning as a landowner property right. It recognizes prescribed fire for its benefits to society, the environment, and the economy of Mississippi. In addition, it outlines the steps that the landowner and practitioner must follow to minimize their liability when using prescribed burning for forest management.

The Mississippi Prescribed Burning Act has been divided into four sections (i.e., 301, 303, 305, and 307). Each section addresses unique policy and legal issues.

SECTION ONE, § 49-19-301 SHORT TITLE
it provides the citation of the new law as the "Mississippi Prescribed Burning Act."

SECTION TWO, § 49-19-303 LEGISLATIVE FINDINGS
it recognizes prescribed burning as a landowner property right. This is a milestone, since prescribed burning previously had no such designation. The legislature has legally and morally placed its stamp of approval on prescribed burning activities in Mississippi.

Furthermore, prescribed burning has been acknowledged for the benefits to society it achieves, namely, the safety of the public, the environment, and the economy of the state. The statute verifies the importance of prescribed burning activities for the reduction of naturally occurring vegetative fuels. These fuels could lead to catastrophic wildfires endangering life and property if they are allowed to accumulate unchecked. The legislature also recognizes the importance of biological diversity in Mississippi's ecosystems. Ecological integrity is stressed with prescribed burning being essential to the perpetuation, restoration, and management of many plant and animal communities. Prescribed burning is viewed as important to prepare forest lands for reforestation, removal of undesirable competing vegetation, promoting nutrient cycling, and control or elimination of forest pathogens.

As the population of the state grows and more pressure is placed on natural resources, liability issues may inhibit the use of prescribed burning. This act forthrightly states that its purpose is to authorize and promote the continued use of prescribed burning. Not only does this act authorize prescribed burning, but it also promotes its future use for ecological, silvicultural, and wildlife management purposes.

SECTION THREE, § 49-19-305 DEFINITIONS

it presents an easily understood definition of "prescribed burning" and clarifies the type of activities within which prescribed burning falls. It also defines two additional terms: certified prescribed burn manager and prescription. To ensure maximum benefits and protection of society, proper training for those who use prescribed burning is necessary. These definitions clarify the concepts required for proper training for those who use prescribed burning.

SECTION FOUR, § 49-19-307 LIABILITY FOR PRESCRIBED BURNS

it sets forth negligence as the measuring stick for liability.

Section 4(1) vigorously establishes simple negligence as a basis for liability in prescribed burning activities in Mississippi. It reaffirms that the standard for liability in Mississippi for prescribed burning activities is simple negligence. In a litigation case, the burden of proving negligence on part of forest landowners or prescribed burners rests with the plaintiff to prove the case by the preponderance of the evidence.

Section 4(2) clearly dictates four requirements in conducting prescribed fire. These four requirements are mandatory and must be closely followed by the prescribed burner. Briefly, these four requirements are: have at least one certified prescribed burn manager on site, prepare and notarize a written prescription plan before burning, obtain a burning permit from the Mississippi Forestry Commission, and be considered in the public interest. Failure to follow these requirements invites a lawsuit based on negligence per se. Negligence per se is conduct which may be declared and treated as negligent conduct without any further argument or proof regarding the surrounding circumstances because there is a violation of a statute. One must be very careful to follow the requirements of the statute. Failure to do so will make a lawsuit more difficult to defend.

Section 4(3) specifies that the Mississippi Forestry Commission shall have the authority to promulgate rules related to this Act. This allows the Commission to make and implement these administrative laws and regulations related to prescribed burning on forest land in Mississippi.

Section 4(4) specifically states that nothing in it shall be construed to limit the civil liability of Section 95-5-25 and Section 97-17-13 of Mississippi Code Annotated.

ADMINISTRATIVE LAW FOR PRESCRIBED BURNING IN MISSISSIPPI

Under the Mississippi Prescribed Burning Act of 1992, the Mississippi Forestry Commission has the authority to regulate burning activities on forest land in Mississippi. These regulations for prescribed burning are administrative law in nature so they are mandatory and also carry the force of law behind them. The current administrative regulations can be divided into three categories: the certification of prescribed burn managers, the guidelines for a prescribed burn prescription, and the issue of a burning permit.

Certification of Prescribed Burn Managers in Mississippi

The Mississippi Forestry Commission has established the criteria that must be met for individuals desiring to become a "Certified prescribed burn manager." At present, there are three approaches to attain the status of certified prescribed burn manager in Mississippi. Unlike other southern states, the Mississippi Prescribed Burning Act does not require any continuing education to maintain certification. The details of these three approaches are as follows:

Approach A: An individual must successfully complete all components of the Prescribed Burning Short Course sponsored by the Department of Forestry at Mississippi State University. The short course typically consists of a multi-day program, including elements from the National Interagency Fire Center (NFIC) S190 and S290 training programs. Individuals are required to write prescribed burning plans for a number of properties, and must successfully pass the short course final examination with a grade of 80 or better. The short course is normally conducted twice a year (spring/fall) in conjunction with the Division of Academic Outreach and Continuing Education at Mississippi State University. Instructors for the course come from the Mississippi Forestry Commission, along with the USDA Forest Service, Mississippi State University, and other organizations.

Approach B: An individual certified in another state may qualify for certification in Mississippi. The individual must contact the Mississippi Forestry Commission and provide proof of their certification at that time. The decision on whether Mississippi certification is extended to the individual is up to the discretion of the Mississippi Forestry Commission. All materials for certification by means other than the Prescribed Burning Short Course at Mississippi State University should be submitted to the Chief, Forest Protection Division of the Mississippi Forestry Commission.

Approach C: An agreement has been made with the Mississippi Forestry Commission and the Department of Forestry at Mississippi State University to allow students enrolled in FO 3202 Forest Fire to become certified prescribed burn managers. This course is offered each spring semester. In order to become certified, the following criteria must be met: (1) Students must pass the final exam in the NIFC S290 training program; (2) Information on the Mississippi Voluntary Smoke Management Screening System must be presented; (3) Students must pass the final exam in the Prescribed Burning Short Course with a grade of 80 or better; and (4) Students must pass the course with an overall grade of at least 70.

Guidelines for Preparing a Prescribed Burn Prescription Plan

Under the authority of the Mississippi Prescribed Burning Act of 1992, the Mississippi Forestry Commission has promulgated guidelines for the prescribed burn prescription. The minimum requirements for information that a prescribed burn prescription should contain are as follows (See a sample plan in **Exhibit III** adapted from Londo et al. 2005):

Requirement 1:
Legal Description of Property – The complete legal description of the property needs to be on the form. This includes the 40, section, township, range, and names of county and state.

Requirement 2:
Name of Owner – The name and address of the property owner as well as the name of the plan preparer need to be included. Mississippi requires that a burn plan be notarized at least one day prior to the day of the burn. The notary's signature and number needs to be placed on the burn plan. In addition, the burn permit number assigned by the Mississippi Forestry Commission on the day of the burn should be documented on the burn plan as well. While not technically necessary, it would provide evidence in the field that a burning permit was obtained in the event that proof of a permit was requested by a law enforcement agency.

Requirement 3:
Stand Description – Stand characteristics need to be described. This includes overstory and understory description. Fuels need to be described as well. Fuels are typically considered to be those on the soil surface. Loadings and models can be determined by using the fuel model and loading methods as described in National Wildfire Coordinating Group (1981). In addition, the topography of the site needs to be taken in to account, as it can have significant effects on fire behavior, microclimatic conditions and fuel loading. It is important to note what soils are present on the site. This is especially true if there are organic soils present. Special precautions should be taken to keep fire away from organic soils.

Requirement 4:
Purpose of the Burn – There are many reasons for conducting a prescribed burn. These reasons include timber management, wildlife habitat management, hazardous fuel reduction, etc.

Requirement 5:
Pre-Burn Information

(5a). Maps:
You need at least two maps. A large-scale area map needs to have the burn area highlighted, along with evidence of smoke management screening. A site-specific map focuses on the area being burned with burning methods and escape routes marked.

(5b). Fire Lanes:
On the site specific map, it is recommended that the corners of the area to be burned are labeled, usually with capitol letters (see attached map as an example). When installing fire lanes, label the fire lane placement based on the letters. This is done for simplicity and safety. Everyone can see where the fire lanes are, based on the map. If the crews are using radios for

communication, it is easy to let everyone know where they are, or where the jump in the fire lane has occurred, etc. Interior fire lanes may be needed. These can be installed and labeled in the same way as those on the exterior. In addition, it is also useful to put in the burn plan any natural, or other man-made fire breaks present. These can include streams, ponds, roads, skid trails, etc.

(5c). Acres to be burned, crew size, equipment needed:
It is important to document how many acres are to be burned, as well as the crew size and equipment needed. In many states, once the burn plan is notarized, it becomes a legally binding document. Therefore, if you are conducting the burn with a smaller crew size than what you initially specified, your liability could increase in the event that something goes wrong.

(5d). Special precautions:
There will usually be something in the vicinity where you are burning which you don't want damaged by your fire. It could be a Streamside Management Zone around a stream, a hunting cabin, etc. Anything of this nature needs to be noted on the burn plan and the site specific map.

(5e). Notify if needed:
Emergency contacts have to be listed on your burn plan because you won't have the time to look up numbers if something goes wrong with your fire. Those listed can be notified prior to the start of burning, to alert them to the fact that you will be burning that day. Also, it is good to put in the names of people who live the vicinity of the area you are burning. Some may have health concerns, or other issues, which would make fire and smoke hazardous for them. Notifying them ahead of time can save you, and them, a lot of time and trouble later on.

(5f). Smoke management:
One of the most important activities when planning a prescribed burn is to determine if there are any smoke sensitive, or smoke critical areas present. This is important for safety and liability concerns. In general, the steps established in Wade and Lunsford (1989) are good procedures to follow for the smoke management plan for any prescribed burn. Major steps include:

1. Plot the direction of the smoke plume – Using the regional scale map, plot the anticipated down wind smoke movement;
2. Identify smoke sensitive areas – Smoke sensitive areas are areas which your smoke could have a negative impact, e.g., towns and cities, airports, roads and highways, hospitals, nursing homes, schools, and farms (chickens especially);
3. Identify smoke critical areas – Smoke critical areas are locations that already have an air quality problem or smoke sensitive areas in the path of your smoke;
4. What to do if smoke critical areas are present – If smoke critical areas are present, you can not burn under the proposed prescription. However, you do have the following options: don't burn at all; change the prescription and go through the smoke management system again; do something other than burning (e.g., use mechanical operations or herbicides).

(5g). Firing techniques:
There are a number of different firing techniques which can be used. Ignition procedures should be documented in the same manner as fire lanes. This allows for consistency on the burn plan,

and is most important for safety. An explanation of firing techniques can be found in Wade and Lunsford (1989).

Requirement 6:

Range of desired weather - The desired weather conditions under which you can conduct the burn needs to be documented here. This includes surface and transport wind speeds, mixing heights, stagnation indices, relative humidity, temperature, and time of day to start the fire. The transport wind speed needs to be at least 3.5 meters per second and the mixing height 500 meters. These conditions are set by Mississippi law, and need to be met before a burning permit can be issued. A stagnation index number also needs to be on the prescribed burning plan. The Stagnation index is an indicator of the length of time conditions that will be appropriate for adequate smoke dispersal. In other words, the stagnation index indicates the length of time for which the prescribed burning permit is valid for. In essence, your fire must be out by the time indicated by the stagnation index.

Specifically, for daytime,
the stagnation indices have the following values:

0 - Burning permitted from sunrise to sunset;
1 - Burning permitted from 1 hour after sunrise until sunset;
2 - Burning permitted from 2 hours after sunrise until sunset; and
3 - Burning permitted from 2 hours after sunrise until 1 hour before sunset.

For night time, these values are:

0 - Burning permitted from sunset to sunrise;
1 - Burning permitted until 2 hours before sunrise;
2 - Burning permitted until 4 hours after sunrise; and
3 - No burning permitted.

Requirement 7:

Summary of burn - Once the burn is completed, you need to conduct a summary of the burn. How many acres actually burned, the techniques used (which should match up with what you said you were going to do), the time the fire was set, time period for which your permit was valid (check with your state forestry office) as well as weather conditions on the day of the burn. Depending on the objectives of the burn, you can include the number of acres of jump overs, measures of crown scorch, etc., if any such items have occurred.

Burning Permit for Prescribed burning

Currently, the Mississippi Forestry Commission requires forest landowners and/or burners to get a burn permit before burning. Contact your county office for permit information. Only when conditions to burn are favorable, can the burn permit be granted. These favorable conditions include a minimum mixing height of 500 meters and a transport wind speed of at least 3.5 meters per second. These requirements are to insure that federal air quality laws are followed.

SUMMARY

The potential liability associated with escaped fires and smoke has been a widespread concern to forest landowners and managers in using prescribed burning on private forest land. In this publication, the legal environment of prescribed fire in Mississippi has been reviewed and summarized from the perspective of common law, statutory law, and administrative law. The review of these relevant Mississippi cases in the past century revealed that the standard of care associated with simple negligence has been required for the intentional use of fire on forest land with a lawful purpose. Furthermore, the enactment of the Mississippi Prescribed Burning Act in 1992 confirmed and codified these principles in the statute. The Act also explicitly recognizes that prescribed burning is a property right and land management tool that greatly benefits society, the environment, and the economy of the state. This statute on prescribed burning activities has been welcomed by the forestry community in Mississippi.

Along with the passage of the Prescribed Burning Act, there has been increasing administrative regulations on the use of prescribed burning in Mississippi. The requirement of certified prescribed burn manager, coupled with the written, notarized burn prescription, should foster a higher degree of professionalism. Prescribed burners now know that so long as they conduct prescribed burns in conformity with the requirements of the law, they will not be held liable for damage or injury caused by fire or resulting smoke unless negligence is proven.

The Mississippi Prescribed Burning Act of 1992 has not been challenged in or explained by the courts in Mississippi. It remains to be seen how the courts will treat independent contractors in relation to the Respondeat Superior doctrine. The answer may be revealed through future court decisions that interpret that portion of the statute. While prescribed fire will continue to be an important management tool for the forest land community, its legal environment along with the liability issues merit further observation and analysis in the future.

USEFUL LINKS TO PRESCRIBED BURNING

Mississippi Forestry Association
msforestry.net

Mississippi Forestry Commission
www.mfc.state.ms.us

Mississippi State University Extension Service
(MSU-CARES, Coordinated Assess to the Research and Extension System)
msucares.com/forestry/index.html

Mississippi Statutes (e.g., the Prescribed Burning Act of 1992)
www.mscode.com

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EXHIBIT 1

Gulf Oil Corp. v. Turner, 235 So.2d 464 (MS Sup. 1970)

GULF OIL CORP. v. Mrs. Alice D. TURNER

No. 45803
Supreme Court of Mississippi
235 So. 2d 464; 1970 Miss. LEXIS 1453
May 11, 1970

SUBSEQUENT HISTORY: Rehearing Denied June 8, 1970.
DISPOSITION: Affirmed.
COUNSEL: M. M. Roberts, S. Wayne Easterling, Hattiesburg, for Appellant. William E. Andrews, Jr., Purvis, Zachary, Weldy & Ingram, Hattiesburg, for Appellee.
JUDGES: Gillespie, Presiding, Justice, wrote the opinion. Rodgers, Patterson, Smith and Robertson, JJ., concur.

OPINION BY: GILLESPIE
OPINION:

Mrs. Alice D. Turner (hereinafter plaintiff) sued Daniel J. Nicovich, Bradley Brothers, which is a corporation, Gulf Oil Corporation, Broome Construction Company, Inc., and Capitol Transport Company, Inc., in the Circuit Court of Lamar County for injuries sustained in a vehicular collision. The suit was non-suited as to Capitol Transport Company, Inc. Judgment was rendered in favor of plaintiff against Gulf only on the following comprehensive verdict returned by the jury:

1. We, the jury, find that Broome Construction Co., Inc., is free of any negligence by a unanimous vote.
2. We, the jury, find that Bradley Bros., Inc., is free of any negligence by a unanimous vote - let that also stand for the driver Daniel J. Nicovich.
3. We, the jury find that Gulf Oil Corp. is guilty of negligence as stated in the plead (sic) of the plaintiff by a unanimous vote.
4. We, the jury, find Mrs. Alice D. Turner guilty of some negligence by a unanimous vote.
5. We, the jury, find or award to the plaintiff, Mrs. Alice D. Turner, a sum of $55,000.

There from Gulf appeals. The judgment below is affirmed.

I.

Gulf contends that the trial court erroneously refused to instruct the jury that it was entitled to a verdict as a matter of law. With regard to deciding a case as a matter of law which necessitates a finding that the evidence was insufficient to establish a jury issue, the oft-announced rule is that this Court must view the evidence in the light most favorable to the party in whose favor the jury returned the verdict. We must consider as true all evidence favorable to the successful party and assume that the jury drew every permissible inference in reaching its verdict. All conflicts in the evidence are resolved in favor of the prevailing party and this Court may not consider any evidence favorable to the other party except that which is uncontradicted. The facts of the present case are recited with these observations as a guide, and the ultimate facts, not the evidence, are so stated.

Gulf, as operator of an oil refinery in Lamar County, Mississippi, had a contract with Broome whereby Broome performed maintenance and construction services for Gulf as were from time to time required. At 7:30 on the morning of February 7, 1968, upon Gulf's request, Broome furnished one of its employees, Edwin Hendrix, to assist Gulf in the burning of a wooded area south of Black Creek, west of U.S. Highway 11 and near Gulf's refinery. Hendrix reported to W. E. Lott, a foreman or supervisor for Gulf; as instructed by Lott, Hendrix went with Lott to the northwest corner of the one hundred acre tract where both of them proceeded to set fire to the woods at several points. About 8:30 a.m. both Lott and Hendrix departed, leaving no one in charge of the burning woods which were separated from the adjacent woodlands by several roads and Black Creek. At 10:00 a.m. the wind was blowing from the northwest at ten miles per hour and the fire had reached that part of the woods bordering U.S. Highway 11. Dense clouds of smoke were crossing the highway.

About 10:15 a.m. the Bradley Brothers truck was traveling south on Highway 11 when its driver Nicovich observed the smoke about a quarter of a mile before arriving at Black Creek. At times he could see through it but some gusts of smoke were too dense to enable him to see ahead. Nicovich was proceeding behind a tank truck purportedly owned by Capitol Transport Company. Both trucks entered the area of the smoke at a speed of twenty miles per hour. After Nicovich had progressed a distance of about one hundred feet in the smoke, the vehicle driven by plaintiff collided with the rear of his truck. Plaintiff saw the smoke as she approached Black Creek at a speed of sixty to sixty-five miles per hour. She turned her lights on and released the pressure of the accelerator which slowed her vehicle to some extent. As she entered the smoke area a dense blanket of black smoke enveloped her car; thereafter she was unable to remember what transpired.

An official of the Mississippi Forestry Commission stated that the day of the accident was unsuitable for burning woods according to that day's fire danger rating which was ascertained by computing such matters as wind velocity, relative humidity, temperature, and ground moisture conditions. Neither Gulf nor Broome contacted the Forestry Commission before setting the fire.

The contention that Gulf was entitled to a verdict as a matter of law is based on several separate grounds.

A. Gulf maintains that the exoneration of Broome by the jury is likewise an exoneration of Gulf with whom Broome had contracted to burn the woods since the jury must find Broome liable before it could render a verdict against Gulf. The decisions of when to burn the woods and where to set the fires were made by Gulf whose foreman Lott not only directed Broome's employee Hendrix but who personally assisted in igniting the fires. Thus, the firing of the woods was the direct act of Lott, Gulf's employee. Moreover, even if only liable vicariously because of the acts of Broome's employee, Gulf could not take advantage of the exoneration of Broome. In Gulf Refining Co. v. Myrick, 220 Miss. 429, 71 So.2d 217 (1954), the jury exonerated Gulf's truck driver yet rendered a verdict against Gulf based on the negligence of said truck driver; the judgment against Gulf was affirmed.

B. Gulf asserts that the sole proximate cause of the accident was the negligence of plaintiff. Plaintiff was negligent, and the jury specifically so found. We are of the opinion that the authorities cited by Gulf do not sustain its position that plaintiff's negligence was the independent, intervening, sole cause of the accident. In our opinion Gulf was negligent and that its negligence was a concurrent contributory cause to the accident. Keith v. Yazoo & M.V.R.Co., 168 Miss. 519, 151 So. 916 (1934). In the recently decided case of Merchants Co. v. Way, 235 So.2d 278 (Miss. 1970), suit was brought for the wrongful death of Mrs. Way against Merchants Company, owner of a truck, into the rear of which Mrs. Way's husband collided, resulting in the death of Mrs. Way. The accident, which occurred in smoke from burning woods, was similar to the present one. In that case this Court reversed the judgment against

Merchants Company and held that the sole proximate cause of the accident was the negligence of Mr. Way. In the Way case, only the Merchants Company was sued, without joining the party, if any, responsible for the woods being ablaze. The Court found as a matter of law that Merchants Company was not guilty of negligence; thus the sole proximate cause of the accident was Mr. Way, so far as that suit was concerned.

C. Gulf further argues that neither Broome nor Gulf was negligent in setting the woods on fire. Gulf asserts that the fire was ignited at a time when the wind was not blowing, the grass and other material were moist, and nothing revealed that wind or other factors which might affect the safety of burning the woods could have been anticipated. The basis of this argument is invalid. Neither Gulf nor Broome called the Forestry Commission at its station only nine miles away or the weather bureau to determine whether the day was suitable for burning woods. They did not wait until later in the day to determine what wind conditions would develop. The Texas case cited, if in point, must yield to our own case of Keith v. Yazoo & M.V.R.Co., supra, wherein the Court said:

The jury were warranted in finding that the fire producing the smoke was negligently set out on a windy day, that the fire was set to highly inflammable dry matter and in close proximity to a public highway, and that the smoke would be blown on and across the highway, causing thereby an effectual barricade. In this situation, we think a jury would be warranted in finding that the agent and employees of the railroad company might reasonably foresee that some injury might result to those who had the right to travel the public highway at that and other points. (168 Miss. at 523, 524, 151 So. at 917).

D. Gulf also maintains that it was entitled to judgment as a matter of law because if liability exists, then Broome is primarily responsible. This argument is founded upon the assertion that Broome was an independent contractor responsible for burning the woods, and that Lott in assisting Hendrix in setting out the fire was a loaned employee of Broome. There is no merit in this argument. Hendrix, Broome's employee, was a laborer with instructions to do what Lott, Gulf's foreman, directed him to do. Lott controlled Hendrix in burning the woods. Broome's employee was not independent of Gulf nor was Lott a loaned employee of Broome.

II.

Gulf assigns as error the action of the trial court in not admitting in evidence the contract between Gulf and Broome, which was introduced and admitted for identification only. By its terms Broome contracted to perform as an independent contractor maintenance services as required by Gulf. It should be noted that on this appeal Gulf named Broome as an appellee and that Broom filed a brief as an appellee. Gulf contends that the judgment either should be corrected to render it joint and several against Gulf and Broome, or corrected to reverse and render as to Gulf, or that the case should be remanded for a new trial. No authority is brought forward in support of this argument. This is a personal injury suit sounding solely in tort. Gulf attempts to create a contractual issue between it and Broome based on the therein contained indemnity clause. We hold that the court correctly refused to admit the contract in evidence.

III.

Gulf maintains that the verdict of $55,000 is grossly excessive. The demand was for $110,000. Plaintiff, who was forty-seven years of age at the time of her injury, sustained serious injuries to her lungs and suffered multiple rib fractures, a crushed chest wall, a fracture of the right thigh, deep lacerations of the forehead and an injury to her ankle. She developed pneumonia, atelectasis of the lungs and other respiratory difficulty necessitating a tracheostomy. She had an operation upon her leg, stayed in the hospital forty-nine days and will require one additional operation. Her medical bills to date of trial amounted to $7,921.78 despite the prospect of an additional operation. Plaintiff has a twenty-five percent permanent impairment of the lower right extremity. Plaintiff, a licensed practical nurse with an earning capacity of $285 to $350 per month, was at the time of the trial still unable to return to work. Her injuries were such that testimony reveals that she would have in all probability died at the scene except for the services of Dr. Lloyd L. Broadus of Purvis, Mississippi, who immediately responded to a call for assistance. Since plaintiff's chest wall was crushed, she was unable to breathe and had turned blue. The doctor manipulated her body to allow her breathing to be restored. We cannot say that the damages are so grossly excessive as to justify intervention by this Court, notwithstanding plaintiff's contributory negligence.

We have carefully considered the other questions raised in Gulf's brief. Having reviewed the record as a whole and the arguments of counsel, we find no reversible error.

Affirmed.

RODGERS, PATTERSON, SMITH and ROBERTSON, JJ., concur.

EXHIBIT 11

Mississippi Prescribed Burning Act of 1992

Mississippi Code of 1972 Annotated
Title 49. Conservation and Ecology
Chapter 19. Forests and Forest Protection

§ 49-19-301. Short title

Sections 49-19-301 through 49-19-307 may be cited as the "Mississippi Prescribed Burning Act."

§ 49-19-303. Legislative findings

(1) The application of prescribed burning is a landowner property right and a land management tool that benefits the safety of the public, the environment and the economy of Mississippi. Pursuant thereto, the Legislature finds that:

(a) Prescribed burning reduces naturally occurring vegetative fuels within wild land areas. Reduction of the fuel load reduces the risk and severity of major catastrophic wildfire, thereby reducing the threat of loss of life and property, particularly in urbanizing areas.

(b) Most of Mississippi's natural communities require periodic fire for maintenance of their ecological integrity. Prescribed burning is essential to the perpetuation, restoration and management of many plant and animal communities. Significant loss of the state's biological diversity will occur if fire is excluded from fire-dependent systems.

(c) Forest lands constitute significant economic, biological and aesthetic resources of statewide importance. Prescribed burning on forest land prepares sites for reforestation, removes undesirable competing vegetation, expedites nutrient cycling and controls or eliminates certain forest pathogens.

(d) The state manages hundreds of thousands of acres of land for parks, wildlife management areas, forests and other public purposes. The use of prescribed burning for management of public lands is essential to maintain the specific resource values for which these lands were acquired.

(e) Proper training in the use of prescribed burning is necessary to ensure maximum benefits and protection for the public.

(f) As Mississippi's population continues to grow, pressures from liability issues and nuisance complaints inhibit the use of prescribed burning.

(2) It is the purpose of §§ 49-19-301 through 49-19-307 to authorize and promote the continued use of prescribed burning for ecological, silvicultural and wildlife management purposes.

§ 49-19-305. Definitions

As used in this section unless the context requires otherwise:

(a) "Prescribed burning" means the controlled application of fire to naturally occurring vegetative fuels for ecological, silvicultural and wildlife management purposes under specified environmental conditions and the following of appropriate precautionary measures which cause the fire to be confined to a predetermined area and accomplishes the planned land management objectives.

(b) "Certified prescribed burn manager" means an individual or county forester who successfully completes the certification program approved by the Mississippi Forestry Commission.

(c) "Prescription" means a written plan for starting and controlling a prescribed burn to accomplish the ecological, silvicultural and wildlife management objectives.

§ 49-19-307. Liability for prescribed burns

(1) No property owner or his agent, conducting a prescribed burn pursuant to the requirements of this section, shall be liable for damage or injury caused by fire or resulting smoke unless negligence is proven.

(2) Prescribed burning conducted under the provisions of this section shall:
(a) Be accomplished only when at least one (1) certified prescribed burn manager is supervising the burn or burns that are being conducted;
(b) Require that a written prescription be prepared and notarized prior to prescribed burning;
(c) Require that a burning permit be obtained from the Mississippi Forestry Commission; and
(d) Be considered in the public interest and shall not constitute a public or private nuisance when conducted pursuant to state air pollution statutes and rules applicable to prescribed burning.

(3) The Mississippi Forestry Commission shall have the authority to promulgate rules for the certification of prescribed burn managers and guidelines for a prescribed burn prescription.

(4) Nothing in this section shall be construed to limit the civil or criminal liability as provided in Section 97-17-13 and Section 95-5-25, Mississippi Code of 1972.

EXHIBIT 111

A Sample Plan of Prescribed Burn Prescription in Mississippi (Adapted from Londo et al. 2005)

40: NE 1/4 SE 1/4 Section: 4 Township: 16N Range: 14E
County: Winston State: Mississippi

Name of Owner

Name: Mississippi State University
Address: Mississippi State, MS 39762
Approved by (Notary): _____________
Burn permit number: ______________

Plan prepared by: Dr. Andrew J. Londo
Date plan written: Feb 28, 2001
Date burn executed: March 10, 2001

Stand Description

1. Overstory: None
2. Understory: Some Light Brush
3. Fuels: Fuel Model 11, Light Slash
4. Topography and soils: Flat, clay loam soils

Purpose of the Burn: This site is being burned for site preparation in order to replant pine.

Pre-Burn Information: (See attached maps)

1.Fire Lanes: Exterior: A-B, B-C, F-H, H-G Interior: D-C, and E-F (To protect SMZ)

2.Other Barriers: Natural: Unnamed Creek in Center of Burn Area
Man Made: Curtis Hamill Road along entire western boundary of burn area and Unnamed road on the north side from pts A-B.

3. Acres to be Burned: ~40
4. Crew Size: 4 with Experience
5. Fire Units: 1 Water Truck; 1 Bulldozer
6. Special Precautions: Keep fire and fire lanes out of SMZ along unnamed creek, experimental plantings to west, mature timber to the north, south and east.
7. Notify (if needed): Winston County Sheriff (662) 773-5881;
Noxubee Wildlife Refuge, (662)323-5548;
Oktibbeha County Sheriff (662) 323-1356;
Oktibbeha County office of the MS Forestry Commission (662) 323 6221;
Winston County office of the MFC (662) 773 2191.
8. Smoke Management
   a. Smoke Sensitive Areas: Wildlife Refuge, Highway 25, any houses in the area, churches
   b. Smoke Critical Areas: None
9. Firing Techniques: Back fire along north side from points A-B along Unnamed Road and From points. E-F along fire break installed along the SMZ. A strip head fire starting at G-H, with strips about 3 Chains apart. When southern compartment burned, then strip head from D-C, with trips about 3 chains apart.

Range of Desired Weather

1. Surface wind speed: 10-15 MPH, SW
2. Transport wind speed: > 3.5m/s
3. Mixing Height: > 500m
4. Stagnation Index: 0-2
5. Relative Humidity: 30-40%
6. Temperature: High 90° Low 70°
7. Time of day to start: 9:00 -10:30 AM

Summary of Burn

1. Acres burned: 43
2. Firing techniques: See Above
3. Date burned: March 10, 2001
4. Time set: 9:30 AM
5. Time permit in effect: Sunrise to 1hr Before Sunset
6. Actual weather conditions

   Surface wind (Dir and Speed) 12mph, s.w.

   Transport Wind: 5 m/s

   Mixing Height 700 m

   Stagnation Index: 1

   Temperature (High) 89 (Low) 71

   Relative Humidity: 34%

   Remarks: Complete burn, with only two minor jump-overs. Jump-overs resulted in an extra acre being burned. No damage done as a result of jump-overs.

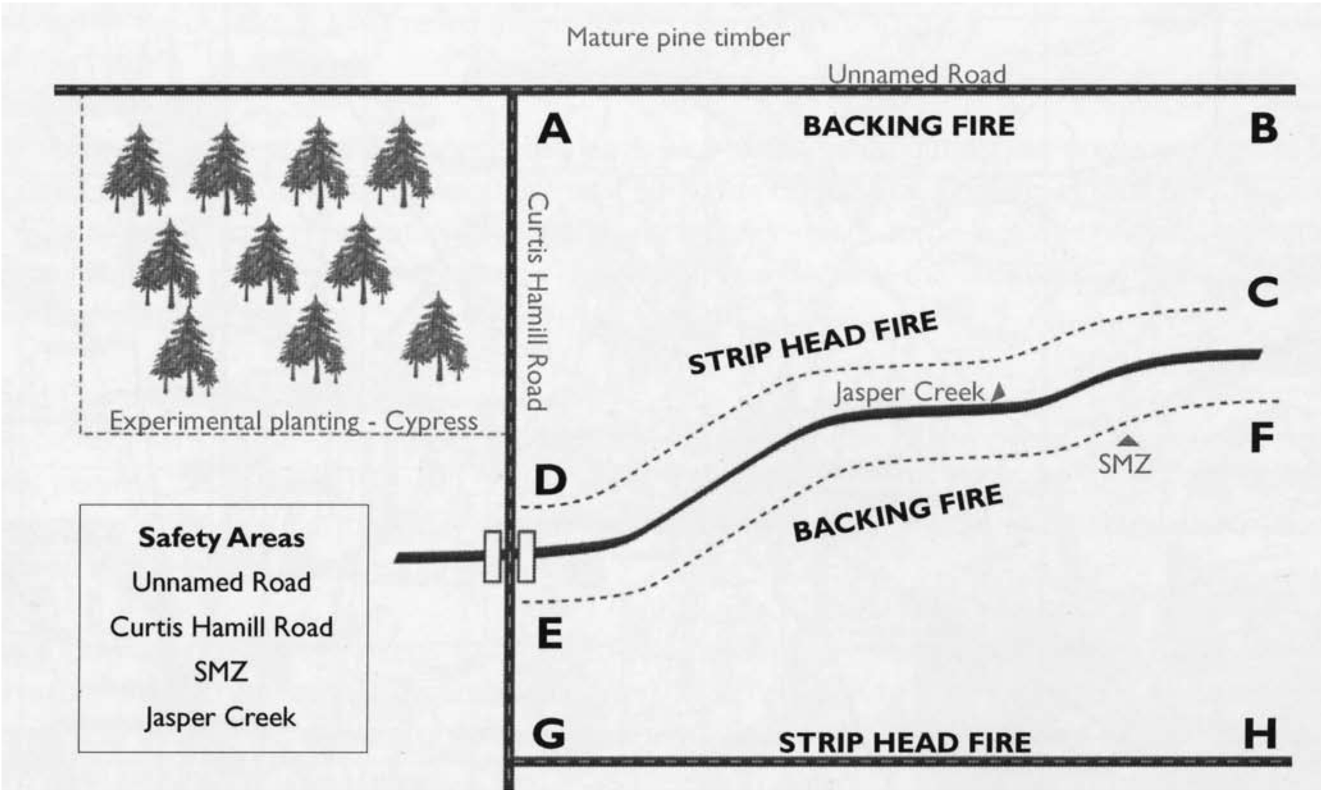


Figure 1 Site Map for the Prescribed Burn Sample Plan (Adapted from Londo et al. 2005)

Figure 2 Area Map for the Prescribed Burn Sample Plan (Adapted from Londo et al. 2005)

FWRC

Mississippi State
UNIVERSITY

Living with Fire: A Guide for Mississippi Homeowners

More than 18 million acres of Mississippi are covered with forestland. About half of this acreage is either pine or a pine/hardwood mix. Located within these pine and pine/hardwood forests are many houses, subdivisions, and communities. As more people move to and build within these forests, the chance of loss or damage from wildfire increases. While large wildfires are uncommon in Mississippi, the conditions for such fires do occur. Many homeowners living in these areas are unaware and unprepared for a wildfire. Since it is not a question of "if" but rather "when" a wildfire will occur, the likelihood of human and property loss is great and constantly growing.

Being able to live safely with fire depends on things you do before a wildfire occurs. These pre-fire actions will not fireproof your home or forests, but they will increase the likelihood of escaping both personal injury and property damage. This publication provides information on the fire environment in which we live, as well as pre-fire actions you can take to protect your home and property from wildfire damage.

The Fire Environment

Fire environment can be defined by surrounding conditions and influences that determine wildfire behavior. Firefighters recognize three parts of the fire environment: weather, topography, and fuels.

Weather includes wind, rain, temperature, relative humidity, and clouds. Weather directly affects wildfire by influencing how wet or dry a fuel is, whether a fire will start, and the speed and direction the fire moves.

Topography is the "lay of the land" and includes both slope and terrain, as well as bodies of water across the landscape. All of these will affect the amount and type of fuels present, as well as how fast and in what direction fire spreads.

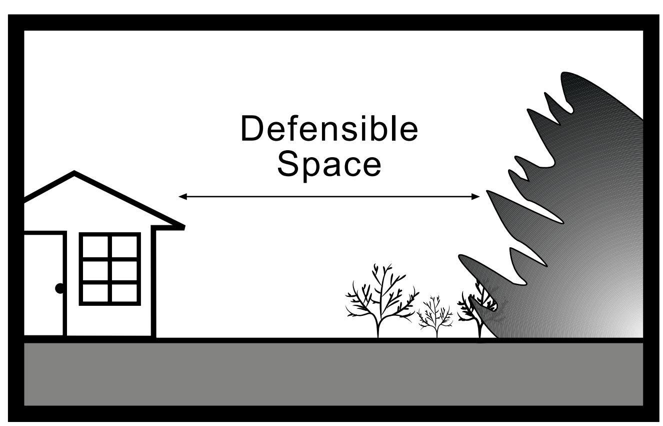
Fuels are anything that will burn, including leaves, grasses and weeds, downed woody materials like branches and tree trunks, living shrubs and trees, manmade debris across the landscape, and even structures like houses. Houses and other buildings become a source of fuel when fires occur. The amount, size, shape, composition, distribution, and moisture content of fuels will affect fire behavior.

Together, the weather, topography, and fuel affect the likelihood of a fire, the speed and direction it will travel, the intensity at which it will burn, and the ability to control and extinguish the fire. You cannot change weather and topography, but you can control the threat of wildfire through fuel management.

Defensible Space

Defensible space is the area between a house or other structure and an oncoming wildfire. You can change plant cover in this space to reduce the threat of wildfire and to help firefighters defend your house. Bare ground surrounding your home is not necessary. Well maintained grass, shrubs, and trees can effectively reduce the threat of wildfire, while maintaining the appearance of the home.

For the most part, you can create defensible space yourself. Watering your lawn, pruning shrubs and trees, selecting appropriate plants, and providing irrigation will help keep your plants green and healthy. Tools needed for these activities are simple items found around most homes: saws, water hoses, rakes, pruning shears, and shovels.



Six Steps to Creating an Effective Defensible Space

Adapted from Carree et al., 1998, and P. Slack, (n.d.).

Step 1: Determine the slope and vegetative cover of your land.

The amount of defensible space you need for your property varies depending on the slope of the landscape and vegetation present. The steeper the slope, the faster a fire can spread and the larger defensible space you need. Also, vegetation will affect how a fire burns and the amount of defensible space needed. **Table 1** lists defensible space recommendations based on percent slopes and common vegetation types in Mississippi.

Step 2: Remove dead vegetation.

Dead vegetation includes dead trees and branches lying on or close to the ground, dried grass, dropped leaves and needles, and stacks of firewood. In most instances, dead vegetation should be removed from defensible space areas. **Table 2** describes the types of dead vegetation you're likely to encounter and recommended actions.

Step 3: Break up continuous vegetation.

Sometimes wildland and landscaped plants grow as an uninterrupted layer instead of being patchy or widely spaced. The more continuous and dense the vegetation, the greater the threat of wildfire. If this condition is present in your defensible space, you should "break it up" by creating a separation between plants or small groups of plants.

Step 4: Remove "ladder fuels."

Vegetation often grows and/or accumulates at varying heights, similar to the rungs of a ladder. This is common in loblolly pine plantations, where dead lower branches become draped with pine needles. Under these conditions, flames from fuels burning at ground level can be carried higher up the tree through these ladder fuels. Vegetation that lets fire move from lower areas to higher ones (from a surface fire to igniting the crown of the tree) is called "ladder fuel." You can correct this problem by removing those ladder fuels.

Within a defensible space, a vertical separation of three times the height of the lower fuel layer is recommended. For example, if a shrub growing close to a pine tree is 3 feet tall, the recommended distance between the shrub and the lowest limbs on the tree would be 9 feet. You can achieve this separation by pruning lower tree branches.

Table 1. Defensible space recommendations (in feet) based on vegetation type and slope percent.

Vegetation type	Slope percent	
	Flat to gently sloping (0–20%)	Moderately steep (21–40%)
Grass	30	100
Shrubs	100	200
Trees	30	100

These recommendations are based on suggestions made by firefighters experienced in protecting homes from wildfire. They are not requirements and do not take precedence over local ordinances.

Table 2. Dead vegetation types and recommended practices for the creation of defensible space.

Dead fuel type	Recommended practices
Standing, dead trees	Remove all standing, dead trees from within the defensible space area.
Downed, dead trees	Remove all downed, dead trees within the defensible space if they have recently fallen and are not embedded in the ground. Downed trees that are embedded and cannot be removed without soil disturbance should be left in place. Remove all exposed branches from embedded, downed trees.
Dead shrubs	Remove all dead shrubs from the defensible space area.
Dried grasses	Once grasses have dried out (cured), remove from the defensible space area.
Dead needles, leaves, branches, and cones (on the ground)	Reduce thick layers of pine needles to a depth of 2 inches or less. Do not remove all needles. Take care not to disturb the duff layer (dark area at the ground surface where needles are decomposing), if present. Remove dead cones, twigs, leaves, and branches.
Dead needles, leaves, branches, and cones (other than on the ground)	Remove all dead leaves, branches, twigs, and needles still attached to living trees and shrubs to a height of 15 feet above the ground. Routinely remove all debris that accumulates on roofs and in rain gutters.
Firewood and other combustible debris	Locate firewood and other combustible debris (wood scraps, grass clippings, leaf piles, and such) at least 30 feet away and uphill, if possible, from the house.

Step 5: Maintain at least 30 feet around your house that is lean, clean, and green.

The area immediately next to your house is very important in creating an effective defensible space. It is also an area that people typically landscape. Within an area at least 30 feet adjacent to the house, vegetation should be kept:

Lean: Small amounts of flammable vegetation.

Clean: No accumulation of dead vegetation or other flammable debris.

Green: Plants that are healthy and green during the fire season are less likely to burn.

Step 6: Maintain vegetation within your defensible space.

Maintaining your defensible space is a continual process and key to keeping your fire-prevention efforts effective. At least once a year, review these defensible space procedures and take appropriate actions.

Other Ways to Protect Your Home from Wildfire

Whether your home is older or brand new, keep these additional considerations in mind:

The roof: Remove dead branches overhanging the roof. Remove any branches within 15 feet of your chimney. Clean all dead leaves and needles from your roof and gutters. Use nonflammable roofing materials.

Construction: Build your home at least 30 feet away from the property line. Use fire-resistant building materials. Limit the size and number of windows in your home that face large areas of vegetation. Install double- or triple-paned windows. Install sprinkler systems within the house. Do not use wooden shingles or siding on your home.

Yard: Stack wood piles at least 30 feet from all structures and clear away flammable vegetation. Locate propane tanks at least 30 feet away from all structures and keep 10 feet of clearance around them. Remove all combustible materials and other debris from your yard. Keep grass mowed and green.

Emergency water supply: Have enough water hoses in good condition to cover your entire property. Keep an emergency water supply that meets fire department standards. If your water comes from a well, consider the option of purchasing an emergency generator to operate the pump during a power failure.

Access: Identify exit routes from your neighborhood. Build roads wide enough for two-way traffic and emergency vehicles. Make sure dead end roads and driveways have enough turn-around space for emergency vehicles. Clear flammable materials and debris at least 10 feet from all roads and driveways. Make sure your street is named or numbered and that street signs are visibly posted at all intersections. Make sure your house and street number are not duplicated anywhere within your county. Post your house address at the beginning of your driveway or on your house if your house is clearly visible from the road.

Outside: Designate an emergency meeting place in a safe area outside your home and practice emergency drills. Keep electric service lines, fuse boxes, and circuit breakers maintained to code.

What to Do When a Wildfire Approaches

If your home is threatened by wildfire, you may be advised to evacuate by fire or law enforcement personnel. This recommendation is meant to protect your life and should be carefully considered. However, you can stay on your property so long as you do not hinder firefighting efforts.

Conclusions

Life in southern forests is enjoyable, but it is not without danger. Even though wildfires are not common in Mississippi, they should be planned for and not dismissed. Some counties may have ordinances addressing defensible space. Check with your local planning and zoning department for further information. Taking precautions to protect your property will increase your chances of escaping serious damage and potential personal injury or death in the event of a wildfire.

For More Information

The following references were used in the development of this publication. They provide a wealth of information concerning ways to protect your home from wildfire.

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Publication 2315 (POD-07-18)

Revised by **A. Brady Self**, PhD, Associate Extension Professor, Forestry, from an earlier edition by Andrew J. Londo, former Extension Professor, Forestry.

Produced by Agricultural Communications.

Extension Service of Mississippi State University, cooperating with U.S. Department of Agriculture. Published in furtherance of Acts of Congress, May 8 and June 30, 1914. GARY B. JACKSON, Director

Prescribed Burning for Pasture Management

MISSISSIPPI STATE UNIVERSITY EXTENSION

Burning has been used for the last 10,000 years to rejuvenate grasslands. Burning pasture or hay fields as a means of managing excess residue is commonly practiced in the southern United States. Fire can be used to control brush and the encroachment of woody plants without harming the grasses because their root systems extend deep into the ground.

Forage producers commonly use burning to stimulate vegetative growth of unproductive or heavily weed-infested pastures. Burning is an inexpensive, labor efficient means of removing unwanted residues or vegetation before forage breaks dormancy. Keep in mind that burning might not be the only management tool needed to control invasive species in a pasture. Prescribed burning must be integrated with rotational grazing to gain the full benefits. Combining the appropriate stocking rate and rest periods with prescribed burning will allow the desirable vegetation to be competitive and help reduce the encroachment of many undesirable plants.

Burning is carried out for a variety of reasons: to remove excessive vegetation, to increase plant productivity by increasing photosynthetic capability, to control weeds and insects, and to reduce diseases where dead biomass could host pathogens. Also, burning changes soil temperature, soil moisture, and short-term nutrient availability, especially nitrogen mineralization.

Although there are some short-term benefits to burning pastures, it can also have long-term detrimental effects, if not managed correctly. Some of those effects include reduction of soil organic matter and nutrients (total nitrogen, total sulfur, carbon/nitrogen ratios, extractable carbon, polysaccharide, ammonium, and available phosphorus), decreased potential for water-holding capacity, injury to some vegetation (especially to short and shallow-rooted grasses), and soil erosion. Heavy rains between burning and green-up may allow the beneficial ash and soil to wash out of the field.

Prescribed burning is planned to achieve a specific objective in a specific area under appropriate conditions at the right time of the year. This will require equipment and a crew to keep the fire under control. A prescribed burn will require some planning to meet certain management goals.

1. **Define the area to be burned.** This could be achieved by using an aerial photo or map of the pasture or property to be burned. It is important to define the conditions of the properties adjacent to the area to be burned and notify the surrounding landowners. Identify the location of fences, gates, power lines, property boundaries, streams, wetlands, roads, trails, nearby buildings and working cattle facilities, etc. Walking the property to be burned is important to identify areas of heavy fuel loads such as matted grass, dead trees, or dry pine trees that could intensify the blaze.

2. **Determine the best time to burn.** Timing of the burn is a critical element for obtaining the desired response. The safety and effectiveness of a prescribed burn can vary according to the region and climatic conditions. Most perennial pastures in Mississippi can be burned from mid-January to early March before green-up. During this time, fire will consume the dead grass without harming the stand. Summer burning is not recommended because of the high temperatures and humidity and the active growth of perennial grasses. The only potential exception here is when hardwoods like sweetgum and green ash have invaded a field or pasture. Sometimes a summer burn is the most affordable and efficient way to kill the hardwood saplings. Burning should be carried out every 3 to 5 years when an excessive amount of dry material is accumulated on the pasture from the previous years, or weeds have infested over 50 percent of the stand. Burning too early may allow weeds to regrow more rapidly, which can increase competition at the time of grass green-up. Early burning will also cause perennial grasses such as bahiagrass and bermudagrass to be more susceptible to late freezes. Burning too late may damage grasses that have begun to green up and reduce the stand.

3. **Create firebreaks.** Firebreaks should allow for the containment of fire within the burn area. Although ponds, plowed fields, and roads could be used as firebreaks, you probably will need to develop some firebreaks that are wide enough to stop the fire. Depending on the type of vegetation in the pasture, the load of biomass, and the topography of the terrain, firebreaks could be created by mowing, plowing, disking, establishing a wet line, or backfiring.

4. **Obtain the necessary workforce.** The number of people needed varies with the size and complexity of a burn. Generally, three to four people are neces-

sary for each fireline—one to ignite the fire, one or two to control the fireline, and one to extinguish all smoldering debris such as logs or stumps. If you are burning close to a highway, it is highly advisable to have a road patrol and signs posted in case smoke blows across the highway and impairs the visibility of drivers.

5. **Use proper equipment.** Drip torches are the most efficient way to ignite a uniform fireline. Flares, propane torches, or matches could work, but these are not as efficient. Crews should have a high-pressure sprayer capable of outputting at least 5 to 10 gallons of water per minute. If burning small pastures that have extremely safe boundaries, a low-pressure, low-volume cattle or field crop sprayer might work. Always make sure there is enough water nearby to refill pumps and sprayers. Backpack sprayers, wet sacks, bow rakes, broom rakes, and swatters could be used to smother fires afterward. Although hand signals could be used as communication in small burns, having band radios or cell phones could make communication more effective. It is also advisable to have farm tractors, four-wheel ATVs, or vehicles available to transport crew, equipment, or water when necessary.

6. **Wear proper clothing.** Crew members should wear clothing made of natural materials such as cotton, leather boots, and leather gloves. Do not wear torn clothing, and avoid any synthetic material such as polyester, plastic, or rubber (rubber boots are acceptable in wet areas). These materials will melt and stick to the skin if they catch fire. Wear goggles and facemasks (dust or painting masks will work). Hard hats are advisable if working around trees, brush, or power lines.

7. **Obtain a permit and notify the necessary authorities.** Any prescribed burn in Mississippi requires a permit in advance from the Mississippi Forestry Commission (**see summary of requirements and regulations, next page**). Contact your county MFC office for permit information. If weather conditions are not favorable for a burn, the permit will not be granted. You must notify the proper authorities (fire department and law enforcement officials, forestry office) and your neighbors before the burn day. Having a cell phone within reach is recommended to request help quickly in case of an emergency. It is also important to have a contingency plan in case the wind shifts, the fire gets out of control, someone gets injured, equipment breaks down, or smoke creates severe visibility problems.

Once you have developed a plan and obtained the proper permits, it is time to prepare for the burning date. Follow these guidelines:

1. **Observe the weather conditions.** It is important to monitor the weather conditions several days ahead of the designated date for burning. It could make or break a prescribed burn. Weather conditions must meet several specific parameters such as wind speed and direction, relative humidity, and air temperature. It is very important to pay attention to ***forecast prediction changes in wind direction***. Wind speed should be ***less than 12 to 15 miles per hour***; humidity should be ***at least 25 percent*** and ideally between 30 and 55 percent; and temperature should be ***80°F or lower***. If these conditions are not met, be prepared to reschedule the burn. ***Do not take chances.*** Because there are so few chances in a year, try to burn as much as possible at a single time if the conditions are favorable. This is also more cost-effective. Do not burn at night because of temperature inversion, which occurs when a layer of warm air is sitting over a layer of cold air. Inversions are common during the night and early morning when cool air is present in the atmosphere. Damp conditions produce more harmful smoke emissions. Cooler temperatures and calmer conditions often cause smoke retention or poor dispersal.

2. **Ignite the fire.** The day of the fire, go over the burn plan with the crew, and check the equipment to make sure that everything is working properly. Before igniting a pasture, we recommend igniting a small test fire in the downwind corner of the burn site to observe the fire behavior and the crew's reaction and performance. This will provide time to correct any issues before beginning the main burn. Once the test fire is completed, start the actual burn by igniting a backfire in the downwind corner. Because a backfire moves against the wind, it will be effective at scorching and killing woody brush and weeds.

   Setting a backfire. Beginning a backfire in late afternoon or early evening will usually allow a slow ignition of backfire lines because humidity is at its lowest point and winds are quietest. Besides controlling the flames, it is also important to control the smoke. Try to avoid burning along roadways where wind will blow toward the road, making it hard for drivers to see.

   It is always recommended to lengthen the backfire by igniting short segments of fireline along the boundary of the burn side that is downwind. ***Never ignite more fire than the crew can easily control.*** The person igniting the fire should pay close attention to wind speed and direction, as well as the location of the crew. Check back along the fireline to make sure that fire has not re-ignited or crossed the firebreak.

Requirements and Recommendations

- Must have a prescription notarized by the MFC at least 1 day before the burn.
  - A burn prescription is a written plan that states the how, what, where, when, and why of burning.
  - It should be site specific.
  - It should include the burning technique(s) to be used.
  - Once notarized, the prescription becomes a legally binding document.
- Must have a permit from the MFC on the day of the burn.
- Must be in the public interest (the prescribed burn is for site preparation, hazard fuel reduction, wildlife management, or other similar issue).
- Take time to scout the site and surrounding areas. Know the topography, fuel types, species present, and smoke-sensitive areas such as senior citizens' homes, hospitals, highways, chicken houses, and so forth.

Requirements for MFC Burn Permit

- Transport wind speed of approximately 8 mph (3.5 m/s).
- Mixing height of approximately 1,750 feet (500 m).

These conditions will ensure that smoke rises and disperses. Even if you have a permit, you cannot legally burn unless all necessary conditions are met.

1992 Prescribed Burning Act and Liability

- Simple negligence: Pay actual damages and up to $150 fine.
- Gross negligence: Pay actual damages, up to $500 fine, and serve up to 3 months in county jail (misdemeanor).
- A jury determines negligence.
- You do not have to be a certified prescribed burn manager to have a burn on your property. However, without a manager, your risk and liability increase dramatically. If something goes wrong, particularly with smoke management, you can be found in gross negligence.
- MFC foresters can immediately issue tickets if they are called to a site. The fine accounts for labor and materials used to correct the problem.

For more information, see *The Legal Environment for Prescribed Burning in Mississippi* (FWRC publication FO 351).

Setting a flank and headfire. Continue working along the perimeter of the burn area, igniting the flanks. A flankfire moves at right angles to the wind and burns more quickly than a backfire. Be cautious because with a wind shift, a flankfire could turn into a fast-burning headfire. The backfires and flankfires should create a firebreak, or burned ground, around most of the perimeter of the burned pasture. Then you can ignite the headfire. Keep in mind that headfires could spread quickly, have long flames, and create the most heat. Because fire escapes usually happen when igniting a headfire, it is recommended that your firebreak be two times wider than the average flame height before igniting a headfire.

3. **Smother the fire and evaluate the results.** After a complete burn, you must make sure the fire is completely out before you leave the premises. One smoldering ember could re-ignite a fire. Check the perimeter of the burned pasture several times. If burning in late afternoon, it might be a good idea to wait until dark when it is easier to see any hot spots. Cut down and extinguish any trees burning near the break. Drench all smoldering debris and hot coals with water. Water mixed with detergent or other surfactants might better penetrate smoldering debris. Do not bury smoldering debris because it can burn for a long time underground.

   Once the work has been done, evaluating the entire the process (from planning to extinguishing) is one of the most important steps. This will ensure that the objectives were met and the operation was safe and efficient. Keep in mind that the burn plan should account for starting a fire and completely finishing it within daylight hours.

A properly planned and executed prescribed burn can be a very effective management tool for pastures or hay fields. Occasional burning of pastures can be an economical and effective management tool; however, repeated, long-term burning of pastures can have a permanent negative effect on soil quality and overall soil health. Repeated burning could cause long-term reduction in yields. Also, soils that are high in fertility may take several years to show the detrimental effects of burning.

Remember: always burn against the wind for better control of the fire; burn before a rain for hot spot control and to incorporate the ash into the ground; and burn early so you can finish the burn before night falls. Also, if fertilization might follow a burn, wait until after the burn to test your soil.

Prescribed burning can be dangerous if improperly or carelessly done. Even if a landowner obtains a fire permit, he/she is still liable for any damages or suppression costs that could occur as a result of the prescribed burn, including fire damages or problems created by smoke. Take precautions and appropriate measures before, during, and after burning to reduce any risks.

The benefits are many and the cost is relatively low, but never forget the danger and cost of poor planning. Get help before you burn. Contact your local forestry commission office and/or your local Extension office for more information on planning and executing a prescribed burn of a pasture or hay field. For more information related to fire bans, burn permits, and fire training, visit ***http://www.mfc.ms.gov***.



Fire Management Practices

Pre-burn. Identify the area to be burned, the burn objectives, and the site characteristics. Make sure firebreaks have been established. Make sure the necessary equipment and crew are ready. Notify the proper authorities and neighbors.

Burn day. Identify the conditions on the day of the burn: wind speed, wind direction, relative humidity, air temperature, fuel load, fuel moisture, and test fire behavior.

Post-burn. Double-check that hotspots are extinguished, smoldering is completed, final perimeter is checked, equipment is collected, and local officials are notified that the fire is out. Assess the success of the prescribed burn.



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Review

A Review on the Dynamics of Prescribed Fire, Tree Mortality, and Injury in Managing Oak Natural Communities to Minimize Economic Loss in North America

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Abstract: The long history of fire in North America spans millennia and is recognized as an important driver in the widespread and long-term dominance of oak species and oak natural communities. Frequent wildfires from about 1850 to 1950 resulted in much forest damage, and gained fire a negative reputation. The lack of fire for the past nearly 100 years due to suppression programs is now indicted as a major cause of widespread oak regeneration failures and loss of fire-dependent natural communities. The use of prescribed fire is increasing in forest management and ecosystem restoration. An understanding of fire effects on trees can provide the basis for the silviculture of restoring and sustaining oak ecosystems. We present an overview of fire-tree wounding interactions, highlight important determinants of fire injury and damage, and discuss several practical situations where fire can be used to favor oak while minimizing damage and devaluation of the forest. We also identify stages in stand development, regeneration methods, and management objectives for which fire has the potential of causing substantial damage and recommend preferred alternative practices.

Keywords: prescribed fire; tree injury; tree decay; tree volume; tree value; oak; silviculture; tree mortality; stand development

1. Introduction

Fire has played a major role in shaping the composition and structure of vegetation for millenia in North America. Fossil records of *Quercus* extend back to 50–55 million years BP [1–3], and oaks were widespread by the end of the Paleogene (~23 million years BP) in the northern hemisphere [3,4]. During the Holocene, increasing fire occurrence, often due to Native American land use practices, favored the dominance of oak-pine (*Quercus/Pinus*) natural communities such as forests, woodlands, and savannas in North America [5–8]. In historic times, fire frequency was highest in the oak region during the early European settlement period [9–11] when settlers saturated the landscape with fire and initiated a wave of fire that rolled from the eastern seaboard to the tallgrass prairies [12,13]. Widespread catastrophic fires, which burned in logging slash circa the 1850s to 1920s, caused severe destruction on millions of acres and took thousands of lives, bringing the need for wildfire control to national attention. In fact, wildfire control was a major purpose for forming state and federal forestry agencies in the early history of forestry in America [14–16]. Wildfire suppression programs have been successful for minimizing the role of fire on the landscape in the short-term. Occasionally, large wildfires (e.g., >4000 ha) break out in severe drought years and high fire danger weather. But for the last 100 years, the influence of fire on forest composition and structure has been minimal, perhaps leading to the creation of novel forest conditions. Once prominent, fire-dependent natural communities such as woodlands and savannas are now rare throughout the US, and oak-pine forests are changing in composition toward other species and developing more complex structure [17–19]. The use of the terms forest, woodland and savanna in this paper follows the definitions of a previous paper [20], and represent categories that span the continuum of increasing tree density, tree canopy cover, tree canopy strata, dominance of woody understory vegetation, and dominance of shade tolerant herbaceous species along the progression from savanna to forest community. The loss of oak forests is a national and global concern [21]. Now, land management agencies and conservation organizations and individuals are increasingly adopting the goals of restoration and sustainable management of oak savannas, woodlands, and forests using prescribed fire in combination with other forestry practices. However, the reintroduction of fire into hardwood forests is a controversial topic due to the potential negative effects of fire on timber volume, quality, and value [22–24].

The history of wildfires during the industrial logging era of the mid-19th to early 20th centuries is widely recognized as the source of high levels of decay and cull (without commercial economic value) timber in eastern hardwood forests [25–28]. Forest fires affect wood volume, quality, and value of individual trees by causing mortality, or wounding tree boles, thereby promoting wood decay and degrade; or of forest stands by causing shifts to less commercially valuable species [22,29]. Wounds can become quite large with increasing fire intensity such as is experienced when wildfire burns through cured logging slash, or in drought years. Decay fungi can infect trees by colonizing wound surfaces and potentially cause substantial loss of wood volume and value over time [22,30–32]. The cumulative negative effects of fire injury persist and exponentially increase over decades in forests because trees are long-lived organisms and decay takes time to advance in them. Therefore, it is not surprising that there is a trend toward a higher proportion of cull percent in stands with increasing historic wildfire frequency in the eastern United States (Figure 1). The highest levels of live cull in standing timber today occur in the Southern, Great Plains Border, and former Prairie Peninsula regions where wildfires were historically more frequent. The Great Plains Border Region commonly experiences annual seasonal drought in late summer and cyclical periods (e.g., 21 to 22 years) of severe drought [33] that promote higher intensity fires and potentially more severe tree wounding. Another contributing factor to high cull percent in forests of Southern and Midwestern hill country is that woods burning persisted longer there than in other regions of the eastern United States [15].

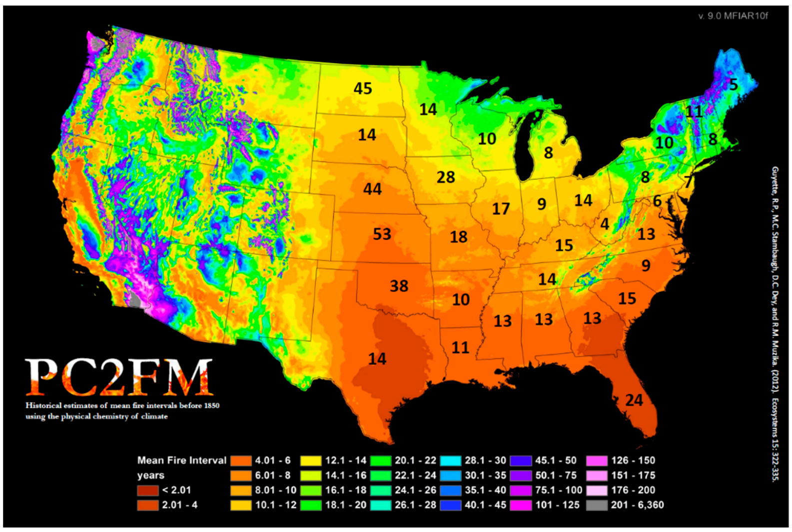

Figure 1. Estimated mean fire interval for low-intensity wildfires before European settlement circa 1650–1850 [34] and percent of total net timber volume that is live cull in modern times according to a national forest inventory [35].

Efforts by federal, state, and county forest fire fighting agencies have been successful in substantially reducing the forest area burned by wildfires through suppression and education in regions of oak forests. Changing economies and demographics in rural areas have also led to a change in the use of fire and cultural attitudes that have resulted in fewer fire ignitions. Even in the face of relatively high fire ignitions, ranging from 2000 to 5000 per year in states like Missouri, Alabama, Florida, Georgia, Tennessee, and North Carolina, effective fire suppression limits the average size of wildfires to <10 ha in most years, and fire has been marginalized in most other states in the eastern US [36]. Consequently, the percent of cull live timber in the East has decreased, for example, from about 50% to 18% since the 1950s in states like Missouri [28,37]. In the past 10 to 30 years, prescribed burning to restore oak/pine savannas and woodlands has increased on public and private conservation lands driven by ambitious goals to restore fire-dependent ecosystems, especially in the Great Plains Border Region [38–40]. In addition to these efforts, other federal and state agencies including The Nature Conservancy, National Wild Turkey Federation, and other NGOs are using prescribed burning to restore woodlands and savannas throughout the Midwest and South.

Efforts to restore native communities at such a large-scale followed several decades of debate among resource professionals over the reintroduction of fire, especially in regions where it was a hard-won fight to get people to quit burning their woods. Improvements in timber quality and decreases in the amount of cull in forests following fire suppression were strong testimony to the benefits of keeping fire out of the woods. However, it is also recognized that the loss of fire from oak-pine ecosystems is a major contributor to the loss of savannas and woodlands, and the problem managers are struggling with in sustaining oak-pine forests.

Oak-pine forests, woodlands, and savannas are fire-dependent systems. Their presence on the landscape is essential to conserving native biodiversity, maintaining ecosystem productivity, and promoting resilience and health of landscapes [41–45]. Restoring oak woodlands and savannas on a broad scale increases landscape diversity that is important to the recovery and conservation of threatened and endangered species [46–48]. Lack of early successional habitat in the eastern US, which savannas and open woodlands provide, is a major concern in wildlife conservation [49–51]. Savannas and woodlands support some of the highest levels of plant diversity [52–54], which begets a greater abundance of varied resources and habitats needed to conserve threatened and endangered wildlife species [55–58]. Both the dominance of oak tree crowns in the canopy and oak litter on the forest floor increase ecosystem productivity by supporting a greater diversity and abundance of invertebrates involved in energy and nutrient cycles than those communities without oak [59–62]. In this era of ecosystem restoration, using fire to restore native communities puts emphasis on ecological benefits such as increased native plant diversity and improved habitat quality for species that prefer woodlands and savannas. However, age-old concerns about fire damage to trees and forests remain and should be considered when planning management approaches and silvicultural prescriptions for restoring and sustaining these highly valued oak forest, woodland, and savanna ecosystems.

This paper provides an overview of prescribed fire-caused damage in oak-dominated systems in North America, the factors that influence damage to trees, and how management can be modified to minimize financial loss of the oak component in forests, woodlands, and savannas. Several management scenarios are used to explore the appropriateness of fire at key stages in the process of restoring and managing oak regeneration and development of oak ecosystems. A previous paper [63] published an excellent synthesis of the role of fire in the life cycle of an oak forest with an emphasis on biology and ecology. We used a similar life cycle approach to select the scenarios for discussion. They are common stand conditions and developmental stages that are key break points in sustaining oak forests, woodlands, and savannas.

2. Types of Fire Injury and Damage

2.1. Tree Mortality

Prescribed surface fires in eastern hardwood forests are capable of killing large mature trees of any species if the intensity and duration of heating is sufficient to cause death of the cambium and foliage (Figure 2). Temperatures (e.g., at 25.4 cm above the ground) in low-intensity, dormant season (e.g., March–April) fires can average 149 °C to >204 °C [64–66], i.e., high enough to kill living organisms and plant tissue, and cause tree mortality by stem girdling [67–69]. However, bark is capable of protecting trees from complete girdling of the stem [70,71]. In mixed-oak forests, relatively high percentages of overstory trees (>11.4 cm dbh) may be scarred on the lower bole from low-intensity fires but usually mortality is relatively low (e.g., <5% basal area or <8% of stem density) after single or repeated low-intensity fires [68,72–74]. Mature, large diameter pines are more resistant to fire mortality than are most hardwood species of similar sizes [75]. Higher fire intensity and increased exposure to high temperatures are needed to kill large trees (e.g., >25 cm dbh), which may occur locally during low-intensity fires where accumulations of fuels occur near the base of individual trees [76]. Tree mortality due to burning increases with decreasing tree diameter and is highest in the seedling size class; and increasing numbers of fires and fire frequency results in higher mortality in species that are able to resprout after being top-killed (i.e., where fire kills the shoot but not the root or adventitious buds clustered near the root collar) [77–79].

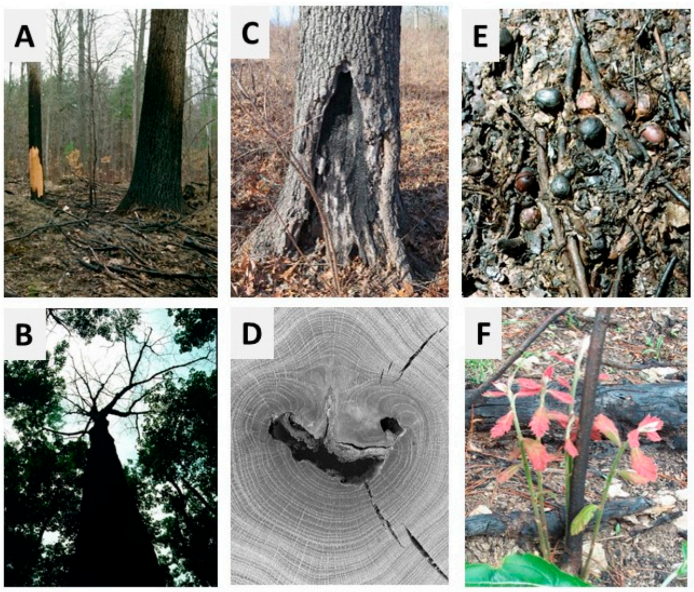

Figure 2. Injury and damage from prescribed burning may include (**A**,**B**) mortality of large overstory trees, though this occurs infrequently, and is usually associated with large concentrations of slash fuels around the base of the tree. Small to large wounds at the base of the tree (**C**), where the heat of fire has killed the cambium, may permit wood decaying fungi entry into the tree. Some tree species, such as those in the white oak group, are able to compartmentalize the injury and minimize the area of damage by decay (**D**). Low intensity fires cause high mortality in oak acorns that are mixed in the surface litter (**E**). Young seedlings of most species are at high risk to fire mortality but larger seedlings and saplings are able to resprout after fire top-kills the main stem (**F**), oaks have a relatively high capacity to do this, even in frequent fire regimes.

2.2. Stem Top-Kill

Low-intensity fires are capable of causing death of the entire cambium on smaller diameter trees of any species. The bark of saplings and seedlings is relatively thin and offers less insulating protection to the cambium than mature, large diameter trees of most hardwood species [80]. Complete stem girdling by fire results in the death of the main stem above the damage. Many hardwood species are able to produce vegetative sprouts after girdling of the stem by one fire [67,72]. Whether top-kill by fire is considered a benefit or damage depends on management goals, silvicultural objectives and the stage of stand development [63]. In sustaining oak forests, top-kill is a positive fire effect when used to favor the development of large and competitive oak reproduction by increasing available light to oak reproduction through decreases in the overhead canopy density in the mid- and overstory and competition in the regeneration cohort [81]. In restoring oak woodlands and savannas, repeated fires that cause mortality or top-kill of woody stems are desirable when trying to reduce stem density and forest cover to promote native ground flora diversity and desirable open woody structure. In contrast, repeated top-kill of hardwood sprouts can adversely retard the recruitment of oaks and other desirable reproduction into the overstory [82], causing years of lost growth and delaying maturity of a fully-stocked forest overstory.

2.3. Bole Wounding and Decay

Low intensity fires can kill cambial tissue at the base of overstory tree boles and create wounds, though not all trees are wounded in a fire [71]. Whether a tree is wounded or not depends largely on fire behavior (i.e., temperature, flame length, and duration of heating) at any one location within the burn unit, and tree characteristics such as species, size, and bark (see below). Numerous fire history studies, which sample the trees in a stand to document fire occurrence as evidenced by scars in tree rings, report that most fires in oak ecosystems are low intensity and scar on average about 10% of the sample trees, but occasionally 60% or more of the trees are scarred when moderate to high intensity fires burn [83]. The observed proportion of trees scarred in long-term frequent prescribed fire studies ranges from <20% to 70% of surviving trees (>11.4 cm dbh), depending on tree species and size, slope, aspect, fire season and frequency, and fuel loading [24,29,74]. The threat of scarring and scar size is substantially reduced in larger, thick-barked tree species. The probability of scarring is higher on southern aspects and steeper upper slopes and ridgetops where fire intensity may be higher than on mesic sites and flat terrain [74,84,85]. Growing season fires have a greater potential to cause scarring because plants are physiologically active and ambient temperatures are closer to lethal temperatures that cause plant tissue necrosis [86]. A regime of annual burning often results in less scarring than less frequent fires (e.g., every 4–5 years) because fuel loading is kept low and fine fuel continuity may be patchy [29,83,87,88]. When fires burn periodically in hardwood forests, fine fuel loading is able to recover to near maximum levels as defined by the decomposition equilibrium fuel loading for that system [89], hence fires burn with more intensity and longer duration. When overstory thinning is done to increase residual tree growth or to aid in developing woodland/savanna structure, subsequent fires usually increase the percent of trees scarred due to increased fuel loading from the thinning [74]. However, a previous paper [84] found that burning immediately after thinning in upland mixed-oak forests, before the newly added fuels had cured, actually reduced fire temperature, rate of spread and, hence, intensity. When heavy fuels from shelterwood harvesting are allowed to cure, e.g., 2 to 4 years, before prescribed burning, then severe mortality and bole damage is probable when heavy slash is within 1 m of the boles of oaks, hickories and yellow-poplar [76].

Open fire scars provide opportunities for wood decaying fungi to colonize and infect trees. Large scars with exposed wood that remain open and moist for long periods provide good environments for fungal colonization and development. However, fire scars are often small and the bark commonly remains intact, covering the injury after low-intensity fires in upland oak forests of the Central Hardwood region [71]. Loss of volume and value in fire scarred oak trees may be relatively minor in the short-term (<10 years), but with time, advanced decay can result in substantial value losses [22,32]. Although larger diameter trees are less likely to scar, when they do suffer wounding that results in open-faced scars, the potential is high for loss to decay over the ensuing decades [31]. If young, vigorous trees are able to rapidly enclose the open wound in a relatively short period of time, then the loss to decay can be minimized. Pole (dbh ranging from approximately 13 to 28 cm) and small sawtimber (dbh > 28 cm) trees are at risk of losing substantial volume and value in the lower log when they suffer open-faced scars because they will remain in the stand for decades before reaching maturity, which allows for advanced decay to develop. Considering that about one-third of the total standing volume is in the lowest 2.4 m log of mature trees, fire injury leading to wood decay at the base of a tree has significant potential effects on merchantable volume and value. Even where timber production is not the primary management concern such as in woodland and savanna restoration, the longevity of mature overstory trees may be compromised by advance decay in the boles of fire-scarred trees because trees are more susceptible to stem breakage and blowdown during wind and ice storms [70]. However, there are positive ecological benefits to scarring and decay development in large trees that lead to an increase in number of wildlife den and cavity trees. This is important to recovery of biodiversity in second growth mature forests because they have significantly fewer cavity and den trees than primary old growth forests [90].

3. Determinants of Fire Injury and Damage

Trees can resist being injured by fire, or they can minimize the damage following injury by defensive responses that confine damage (e.g., wood decay) to the area of initial injury.

3.1. Tree Species

Species-specific growth strategies and morphological characteristics result in different responses among species following fire, with oaks generally better adapted to persist following burning than many competitors. The susceptibility to cambial death and top-kill by a single fire is nearly equal for seedlings and smaller sapling-sized stems, almost regardless of species [67]. Mortality is high in the smallest of seedlings and new germinants, even in the oaks [91]. However, large oak seedlings and saplings are better able to persist with repeated burning than their major competitors [81]. In general, oak species have a distinct advantage over competitors for surviving fire because they preferentially allocate carbohydrates to root growth and have an abundance of dormant buds commonly located in the soil where they are insulated from the heat of a fire [19,66,84,92,93]. Nonetheless, oak stems < 10 cm dbh are susceptible to top-kill, but the larger stems have a high capacity to persist by sprouting [94], especially when there is adequate light for growth during the fire-free period. However, sprouting ability varies by species and begins to decline beyond a species-specific diameter threshold, which is usually in the pole-sized and small sawtimber size classes [19,95]. Lastly, species differences in ability to resist fire mortality and injury become more pronounced in the larger diameter size classes, and this has much to do with differences in bark characteristics (see below).

3.2. Tree Size

Size influences a tree's ability to sprout after fire-caused top-kill, as do the amount of root carbohydrate reserves and the presence of viable dormant vegetative buds after the fire [67]. Low-intensity fires commonly cause top-kill of hardwood trees < 10 cm dbh and a significant proportion of trees < 20 cm dbh [74,75,77,96]. A previous paper [70] found that post oak (*Q. stellata* Wangenh.) trees that were most likely to be scarred and survive a low-intensity dormant season fire were 10 cm dbh to 20 cm dbh at the time of burning; smaller trees were either top-killed or died. Larger seedlings and saplings of most hardwood species are able to sprout after top-kill caused by a single fire [67,93]. It is in the smaller seedling size classes where oaks are generally better able to persist after repeated fires than similar sized stems of their competitors, provided there is adequate light and time between fires for oak sprouts to continue building their root systems [67,97,98]. However, even oak seedling sprouts can be eliminated from a stand by long-term annual or biennial fires [77,79]. Red maple (*Acer rubrum* L.) can be a troublesome species that competes with oak. If it is allowed to grow to sapling or pole-size, it becomes either resistant to being top-killed, or a persistent sprouter even after several low-intensity fires in the dormant season [99,100]. When large diameter oak trees in the overstory are girdled by fire, they are completely killed, as large diameter oaks, regardless of species, have low sprouting potential [19]. However, as tree diameter increases, so does bark thickness, and this increases a tree's resistance to scarring or girdling of the cambium by fire [101]. But, if a large tree is fire scarred, the potential for volume and value loss from decay is increased because the decay may advance throughout the entire existing bole [31]. The rate of decay and extent of value loss depends, in part, on time and the decay resistance of the heartwood of the species, which varies [102]. Smaller trees, when scarred, may be able to compartmentalize the decay column in the center of the bole (Figure 2D), where wood quality is lower to begin with and where value loss can be minimized during the manufacture of the log [31].

3.3. Bark Characteristics

There are many properties of a tree's bark that influence its ability to insulate the cambium from the heat of a fire: thickness, texture, thermal conductivity, specific heat, and thermal diffusivity. However, it is bark thickness that largely determines the degree of protection of the cambium from lethal temperatures [103]. As trees grow, small increases in bark thickness provide exponentially greater protection from high fire temperatures [80,104]. A previous paper [70] found that the probability of fire scarring and the percent of bole circumference scarred were significantly and negatively related to tree diameter, bark width, radial growth rate, and tree age in post oak (dbh range 10 cm to 71 cm). Another previous paper [105] reported that the probability of surviving a fire increases at the sapling size (5 cm dbh to 10 cm dbh) when the bark starts to achieve sufficient thickness to prevent top-kill, depending on species. Similarly, the authors of a previous paper [70] observed that post oak trees > 10 cm dbh were more likely to survive low-intensity fires without top-kill. There is however a substantial variation in bark thickness, rate of bark growth on the lower bole, and bark texture among species [105–107]. Even with thick bark, scarring can occur in areas of bark fissures [70].

In general, upland species have thicker bark than bottomland species for similar sized trees in eastern North America [105]. Bark thickness is greatest in white oak group species (*Quercus* Section *Quercus*) followed by the red oak group species (*Quercus* Section *Lobatae*). Resistance to scarring decreases in upland oaks from post oak - bur oak (*Q. macrocarpa* Michx.) > white oak (*Q. alba* L.) > black oak (*Q. velutina* Lam.) > southern red oak (*Q. falcata* Michx.) - scarlet oak (*Q. coccinea* Muenchh.) [74,85,101,107]. Species with inherently thinner bark include American beech (*Fagus grandifolia* Ehrh.), flowering dogwood (*Cornus florida* L.), black cherry (*Prunus serotina* Ehrh.), maple (*Acer* spp.), and hickory (*Carya* spp.). The rate of bark thickening during growth is important because faster growth rates allow trees to reach critical thresholds of thickness earlier that are associated with protection of the cambium and survival. Eastern cottonwood (*Populus deltoides* Bart. ex Marsh.) and yellow-poplar (*Liriodendron tulipifera* L.) are both thin-barked, fire sensitive species when trees are small and young, but they have rapid rates of bark growth and are considered resistant to fire scarring as large mature trees [107,108]. In contrast, silver maple (*A. saccharinum* L.) has a slow rate of bark growth all its life and is vulnerable to fire injury even when it is a large tree. Species that have smooth bark texture, such as water oak, are more vulnerable to fire injury to the cambium than are deeply fissured, rough textured species such as chestnut oak (*Q. montana* L.) and bur oak. The bark of southern yellow pines confers a high degree of resistance to fire scarring [74,85]. Once a tree is scarred by a fire, it is more vulnerable to additional scarring in future fires because the bark is thin on the callus wood forming over the original scar.

3.4. Defense against Decay

Diameter growth rate determines how long an open fire scar may provide entry of fungi into the tree's stem. Trees with faster rates of diameter growth are able to close open wounds sooner, thus minimizing the time the wound face is available for fungal colonization. By sealing the wound, the tree also creates an unfavorable anaerobic environment for wood decay organisms, most of whom are aerobic [105,109]. High rates of diameter growth more rapidly restore structural support in the tree's bole and vascular cambial functioning after fire scarring of the bole [73,109]. Growth near the area of injury (wound wood ribs) can be faster than on other portions of the bole [71]. However, frequent fires commonly decrease diameter growth in most species, prolonging the time wounds may remain open for decades if fires are frequent enough (<5 or 10 years) [24,74,101].

3.4.1. Compartmentalization

Compartmentalization is a process whereby trees are able to establish a protective boundary surrounding cells injured by fire [109] (Figure 2D). The boundary is the result of the formation of tyloses and production of waxes, gums, and resins to form a barrier that inhibits cell desiccation and microbial infection. The ability to compartmentalize injuries varies by species. The birches (*Betula* spp.) are less effective at compartmentalizing stem wounds than maples and oaks [105]. Oak species, especially those in the white oak group, have an unusual ability to rapidly compartmentalize fire injuries [71,105]. Authors of a previous paper [71] found that low-intensity dormant season fires produced relatively small scars (scorch height < 102 cm above the ground) that were often concealed by intact bark and were effectively and rapidly compartmentalized in black oak and chestnut oak trees (dbh range 10 cm to 56 cm).

3.4.2. Heartwood Decay Resistance

Resistance to the spread and development of decay in the heartwood due to such factors as the production of toxic biochemicals (e.g., phenolic compounds) or tyloses [110] varies by species and is important to retarding decay that originates from fire scarring. Species of the white oak group (Figure 2D), black locust (*Robinia pseudoacacia* L.), catalpa (*Catalpa* spp.), black cherry, cedar (*Juniperus virginiana* L.), and cypress (*Taxodium* spp.) have heartwood that is resistant to very resistant to decay [102]. Red oak group species, hickories, maples, sweetgum (*Liquidambar styraciflua* L.), yellow-poplar, birches, eastern cottonwood, and American beech have only slight to no resistance to heartwood decay.

3.5. Scar Size and Time Since Wounding

Fungi that infect tree boles through logging or fire scars can cause substantial loss of value and degradation in timber quality over several decades [111]. The authors of a previous paper [30] found that one third of the volume can be defect in white oak, black oak, and scarlet oak butt logs (i.e., the lowest log in a standing tree) within 25 years after the trees received a fire scar. The proportion of butt log that was defect after fire scarring increased with increasing size of fire scar (from 1000 square cm to 6000 square cm) and decreased with increasing size of tree (from about 20 cm dbh to 56 cm dbh) at time of scarring.

Wider scars (Figure 2C) take a longer time for a tree to close by diameter growth. The authors of a previous paper [24] observed that fire scars in mature white oak averaged 8.9 cm in width and took on average 10 years to close in a Missouri oak woodland managed by prescribed burning, but larger scars (23 cm wide) took up to 24 years to close. Fire frequency has an effect on potential scar sizes, with percent of trees scarred and scar size decreasing in annual fire regimes compared to periodic, i.e., every 4 to 5 years [29,83,101]. And burning in thinned stands with slash increases not only percentage of trees scarred but also increases average scar size in oaks [74].

The authors of a previous paper [22] reported that both value and volume loss to decay and lumber degrade in black oak, northern red oak (*Q. rubra* L.), and scarlet oak butt logs increased with increasing prescribed fire severity and initial fire scar size as represented by scar height and scar depth. Most of the devaluation in the butt log resulted from declines in lumber grade and not from volume loss. However, they found that scaled volume loss averaged only 4% and value loss averaged 10% after 14 years from fire injury. They concluded that where <20% of the bole circumference was scarred and scar heights were <51 cm that value loss would be insignificant within 15 years of scarring, and that harvesting the most severely injured trees (e.g., Figure 2C) within 5 years limits value loss. The authors of a previous paper [31] reported also that value and volume loss increased with increasing fire scar size (wound width and length), time since wounding, and tree diameter at the time of scarring. Similar evidence of the extent of fire injury was noted by the authors of a previous paper [71] who measured scorch height on oak boles and found that it was generally <102 cm after low-intensity prescribed fires in Ohio. They observed that most wounds occurred near the ground and were covered by intact bark, small in size, and rapidly and effectively compartmentalized within 2 years of the fire. Thus, losses due to wood decay can be minimized if fire intensity is low and scarred trees are harvested before decay enters the log scaling cylinder and becomes advanced.

The stage of stand development and tree size at the time of fire scarring may influence the probability that decay will substantially reduce wood volume or value by the time the tree is harvested. Fire scars on small diameter trees that survive the injury are necessarily small in size because they are limited by tree size. Closure of the wound is rapid if the tree is vigorous and free-to-grow; this minimizes the likelihood of fungal infection and value loss is negligible [31]. Large diameter trees are better protected from fire scarring by their thick bark, and wounds tend to be small and low on the bole in low-intensity fires. These trees are merchantable and may be removed in a timber harvest soon after the fire (within 10 or 15 years) should fire injury occur, thus minimizing decay development that results in value loss [22,31,108]. In larger sawtimber, injuries on trees generally occur on the large end of the butt log and therefore they are often outside of the scaling cylinder where defect is removed in the slabwood resulting in minimal, if any, decrease in product recovery and value [22]. Fire-scarring of pole-sized and small sawtimber trees that will remain in the stand for 30 years or more are most at risk of advanced decay development and significant loss of volume and value by the time they are harvested. Pole-sized and small sawtimber trees can sustain large-sized scars that take time to heal, during which time they are prone to fungal infections, especially on mesic sites, where fungi populations thrive and moist scar surfaces may be more receptive to infection. Also, prolonged moisture in scars is more likely to occur when scars are in contact with the ground or when they are shaped such that they trap water.

4. Fire in Oak Management

In the next section we present several common scenarios in oak forest, woodland, and savanna management where managers may want or need to use fire, and they are concerned with avoiding or minimizing fire damage to trees. We also discuss the consequences of burning stands at various times in the life cycle of oak in terms of fire damage to trees that results in economic losses [59].

4.1. Scenario 1: Mature Forest with No Oak Advance Reproduction

Prescribed fire can be used to prepare the seedbed in advance of a good acorn crop or in preparation for artificial regeneration of oak by direct seeding or planting seedlings (Figure 3) [112,113]. Fire can reduce: (1) the physical barrier to oak seedling establishment created by deep litter (i.e., >5 cm), (2) seed of competitors stored in the forest floor, and (3) woody competitor density and structure in the mid and understory. Prescribed burning to reduce deep litter layers may need to be repeated because oaks have a periodicity in seed production and good acorn crops occur every 3 to 10 years depending on species. This may allow enough time for hardwood litter to accumulate to pre-burn levels before an abundant seed crop. In Central Hardwood forests, litter can return to 75% of its pre-burn levels in 4 years [89].

Prescribed fire can reduce the supply of viable seed of oak competitors such as black birch (*Betula lenta* L.), yellow-poplar, red maple, and grapevines (*Vitis* spp.) that occur in the seedbank, but repeated fires are needed to effectively lower seed supply, especially if seed-bearing trees occur in and around the stand to continuously add to the seedbank [114]. Removal of seed trees of undesirable competitors in conjunction with a regime of prescribed burning can help to deplete competitor seedbank supply. However, once an adequate supply of acorns falls to the ground, prescribed burning should cease until oak seedlings establish and begin developing a root system (e.g., ≥3 years) because even low intensity fires can kill the majority of an acorn crop and cohort of new seedlings [91,115,116].

Figure 3. Mature mixed-oak forests with complex vertical structure, and lack of oak advance reproduction are common starting conditions for managers interested in sustaining oak forests. The role of prescribed burning is to prepare the site for a good acorn crop and begin reducing the regeneration potential and vigor of oak competitors by diminishing their presence in the seedbank, understory, and midstory.

Shade tolerant midstory trees can dominate regeneration after overstory removal and prescribed burning in this scenario can begin the process of reducing the density of midstory competitors. Low intensity fires are capable of reliably top-killing hardwood trees up to about 10 cm in diameter but many of these stems will resprout after one fire. Although the rate of recovery in growth of competing sprouts is low under the high overstory stocking, repeated burning will be needed to control growth of competing sprouts and to increase their mortality [67,117,118]. The process of preparing the site to receive an abundant crop of acorns and developing a competitive cohort of large oak advance reproduction from that seed crop may take 10 to 30 years using combinations of stand thinning or shelterwood harvesting and prescribed burning [21,81]. Thus, scarring of merchantable stems or trees that will become merchantable by the time of harvest may lead to substantial loss of volume and value due to decay over 20 to 30 years [32,86]. Caution should be used when burning a forest for the first time due to high fuel loading that may have accumulated over decades of no fire. Subsequent fires, if frequent enough (<3 years), will be burning in lighter amounts of litter. Alternative methods for preparing the site for oak regeneration may include mechanical scarification to break up litter barriers and mechanical or herbicide treatment of the midstory. An herbicide application to individual midstory stems has benefits including the avoidance of stem wounding by fire, the prevention of hardwood sprouts from undesirable species, and fewer treatments required for sustained control of competing species. Midstory stems treated by mechanical cutting avoids fire scarring of residual trees, but does not prevent sprouting from cut stems, and it adds immediately to fuel loading that needs to be considered in future burning.

4.2. Scenario 2: Mature Forests with Abundant Small Oak Advance Reproduction

This is a common situation in eastern oak forests that have not been burned in decades. A multitude of seedlings may establish following a bumper acorn crop (Figure 4). Small oak advance reproduction (<30 cm tall and 6 mm in basal diameter) have low regeneration potential, and midstory removal or shelterwood harvesting are often recommended to reduce stand density and deliver more light to the forest floor to promote oak seedling growth [119]. This scenario is not to be confused with the situation where an abundance of oak advance reproduction with small shoots occur as sprouts following a fire that may be arising from larger root systems in stands managed with frequent fire over decades. Prescribed fire can be a useful tool for controlling competing woody stems that are <10 cm dbh, but it has the potential to cause high mortality in oak seedlings with small root systems. Therefore, authors of previous papers [81,120] recommended encouraging oak seedling growth with a shelterwood harvest that removes about 50% of the initial stand basal area, to about B-level stocking, and burning either just before or several years after final overstory removal. Once oak seedlings have become large (e.g., ≥19 mm basal diameter), then moderate- to high-intensity fires can increase the relative abundance of competitive oak reproduction, especially when conducted in the early growing season [81,121]. Waiting as long as possible to conduct the release burn to allow the oak seedlings to grow increases their capacity to sprout vigorously following top-kill from the fire. In unburned forests, basal diameter in oak is an indicator of the size of the root system, which drives sprout growth [122,123]. For several years after each shelterwood harvest, oak seedlings will benefit from increased light levels. Monitoring the reproduction helps determine the need for and timing of prescribed burning. If the shelterwood is completely removed in 3 to 5 years after the initial cut, then fire scarring is not an issue. Scarring of residual trees that are retained for the long-term for wildlife or aesthetic purposes may reduce their longevity due to advanced decay in the lower bole, which renders trees more susceptible to breakage or blowdown in storms. Logging slash that lies within 1.0 m of a residual tree bole may result in mortality or severe scarring after a prescribed fire. Directional felling and managing slash piles during skidding to remove slash from the base of mature trees retained for the long term can greatly reduce the risk of fire damage [76].

Figure 4. Mature mixed-oak forests sometimes have abundant but small oak advance reproduction in the low light environment of the forest understory. The oak seedlings have low regeneration potential and are at risk of mortality by burning, hence efforts to promote their growth usually begin with increasing light by reducing the midstory by thinning or the overstory by shelterwood harvesting. Prescribed fire has a role to play in oak management once oak seedlings grow to larger sizes that are indicative of large root mass and carbohydrate reserve.

4.3. Scenario 3: Stand Initiation Stage after Final Shelterwood Removal or Clearcutting

During the stand initiation stage [124], following clearcutting or final removal of the shelterwood, prescribed burning is effective in promoting oak dominance over competing woody vegetation, as long as the oak advance reproduction is present in sufficient density before harvesting (Figure 5). Periodic fires (e.g., every 3 to 5 years) are useful for increasing the relative abundance of competitive oak seedlings [81]. Moderate to intense fires during early leaf out discriminate more in favor of oak if the oak reproduction is large [121]. As long as the majority of competing stems are <10 cm dbh, burning, within typical prescriptions, will cause top-kill throughout the stand of reproduction, which with time will favor oak dominance. There are no long-term deleterious effects of burning at this stage of stand development unless there are large overstory trees retained for wildlife habitat, aesthetics, or other long-term purposes, such as maintenance of hard mast production. The fire will top-kill the regeneration and new sprouts will be free of fire injury. Scarring in large trees may reduce their life span and compromise their purpose for retention, although while they exist, stem decay may increase their usefulness and value as habitat for den and cavity dependent wildlife species. When the oak regeneration is determined to be adequate and competitive, burning must stop for a sufficiently long period to allow seedling sprouts to recruit into the overstory. This may take 10 to 30 years depending on growth rates and source of reproduction. For example, reproduction from stump sprouts grow initially more rapidly than seedling origin reproduction, reaching 5.8 cm dbh to 7.9 cm dbh in 10-year-old clearcuts in the Missouri Ozarks [125]. White oak saplings that are codominant in Missouri clearcuts grow 3.8 cm in diameter per 10 years on sites of average site quality (SI 18 m to 20 m for oak); at this rate it would take 20 years for a small diameter (2.5 cm dbh) sapling to reach 10 cm dbh and begin to improve its chances of surviving being top-killed by a low-intensity fire [126]. A sufficient fire-free period is crucial to permit recruitment into the overstory before burning is resumed. If timber management is a major objective, there may be no role for fire for the rest of the rotation until it is time to begin again the regeneration process. However, there may be a purpose for periodic fire if required to meet wildlife habitat, conservation of native diversity, control of invasive species, or other objectives.

Figure 5. In the stand initiation phase of forest development, following release of regeneration by clearcutting or final removal of the shelterwood, prescribed burning is highly effective to further promote oak dominance by taking advantage of their superior adaptations to fire when large oak seedling sprouts are competing in open environments.

4.4. Scenario 4: Stem Exclusion Stage, Crown Closure

When regenerating stands reach the stem exclusion stage [124], continued use of prescribed burning indiscriminately causes top-kill and retards stand development (Figure 6). Setting back a stand at this point results in the loss of 15 to 20 years of growth. If oak trees still require release to maintain adequate stocking of dominant stems at this stage, it is better to use mechanical or chemical release methods applied as a crop tree or area-based thinning. The risk of fire scars in larger saplings at this stage can result in substantial degradation and volume loss at the time of harvest, especially if the wounds are large enough to remain open to fungal infections for a decade or more. And practically, it may be difficult to conduct a prescribed burn due to lack of adequate fine fuel loading in the understory, low wind speeds, high fine fuel moisture, and high relative humidity within these dense sapling stands.

Figure 6. Using prescribed burning to thin dense sapling stands is hard to do and is ineffective in releasing individual crop trees since it is rather indiscriminate in what stems are top-killed. Alternative methods such as mechanical cutting or stem injection of herbicides are much more effective in releasing individual oak trees and other desirable species. This is a critical time in stand development where managers can substantially modify future stand composition.

4.5. Scenario 5: Stands Managed by Uneven-Aged Methods

The use of uneven-aged methods, primarily single-tree selection, is not recommended for sustaining oak forests on mesic and hydric sites (Figure 7); however, there is evidence in the xeric forests of the Missouri Ozarks that it may be possible to sustain white oak forests by this method [19,127]. Application of prescribed burning with single-tree selection management is highly likely to cause a large amount of defects in trees by the time they reach sawtimber size. In this silvicultural system, trees are harvested to simultaneously promote regeneration and recruitment into the overstory. Trees of all sizes exist in the stand, and sapling, poles and small sawtimber that sustain fire scars are likely to remain in the stand for decades before being harvested, thus, permitting time for advanced decay to develop. Also, the growth of trees in the mid- and understory is reduced by overstory stocking and this increases the time it takes for fire scars to heal. Burning in uneven-aged stands also can disrupt the distribution of age classes because seedlings and saplings are susceptible to being top-killed or dying. With repeated burning, the regenerating cohort will be concentrated into a single (or few) age classes. The use of group selection has been advocated for oak regeneration because it provides more light to the regeneration than the single-tree method. However, controlling competing vegetation before and after harvesting is problematic in small, random openings located throughout the forest. Without large oak advance reproduction at time of harvest, and control of competing vegetation, group openings typically become dominated by non-oak species [128,129]. The use of fire to control competing vegetation in isolated group openings is operationally impractical due to the small size of openings, lack of natural fire breaks around openings, and group openings are commonly imbedded within a matrix of single-tree selection forest that is vulnerable to fire injury and decay.

Figure 7. In managing forests by uneven-aged methods such as single-tree and group selection the manager is simultaneously developing regeneration, and promoting the recruitment of sapling and pole-sized trees into the overstory at fine scales, i.e., individual and small patch tree gaps. Using prescribed burning to favor oak regeneration in such stands may retard the recruitment process by causing top-kill of saplings, and initiate the decay process by basal scarring saplings and poles, which may develop substantial decay in the lower bole over the decades to maturity.

4.6. Scenario 6: Savanna and Woodland Restoration

Savannas and woodlands were once much more abundant across the landscape in the eastern United States, especially in the border region of the tallgrass prairie and eastern deciduous forests (Figure 8) [130,131]. An increasingly common management goal is to restore these ecosystems where forests now prevail. A primary objective is to reduce stand density using prescribed fire to promote development of native grass and forb ground flora typical of these communities [20]. A challenge in restoration is how to reduce the density of larger overstory trees that have developed over the past 50 years or more since the commencement of fire suppression programs. Moderate- to high-intensity fires are needed to reduce overstory density in the larger size classes, which incidentally have the potential to severely scar the residual overstory trees and reduce their longevity in the overstory. Fire is also less specific about which trees are removed and which remain compared to other methods of stand density management. An alternative to using fire to reduce stand density is to conduct a timber harvest. This permits recovery of wood products, avoids the problem of fire scarring residual trees, and provides better control over the distribution and composition of the final overstory. In addition, timber harvesting produces revenues that can be used to help pay for the management of the unmerchantable woody material, invasive species, or reestablishment of native ground flora. Lower intensity fires can be combined with timber harvesting and mechanical/chemical thinning to achieve other ecological objectives and control small hardwood sprouts. Even though timber quality and value are not foremost on the mind of restoration managers, it is well worth realizing that closed woodlands have nearly the volume of merchantable sawtimber trees as a forest does. And it goes without saying that minimizing fire damage that leads to timber volume and value loss is prudent management in woodland management. When it is time to replace the overstory in woodlands and savannas, a fire-free period is necessary for recruitment. Often there is large oak advance reproduction present because partial overstory density and periodic fire promote oak reproduction.

Figure 8. Managing mature oak forests (**A**) to restore woodlands (**B**) and savannas (**C**) involves reducing tree density in all size classes. Prescribed burning is effective in reducing tree density in the smaller diameter classes (e.g., <10 cm dbh) in the understory and midstory (**B**). Mechanical cutting or herbicide application methods are better for reducing density of larger midstory and overstory trees (**C**).

5. Conclusions

The use of prescribed fire in restoring and sustaining oak ecosystems does not have to have the same negative outcomes as the history of wildfires, with the damage they caused resulting in high amounts of standing live cull volume, especially that which arose out of European settler wildfires burning through a landscape of logging slash generated by regional logging and timber exploitation. Historically, fire was an integral driver of the widespread distribution and dominance of oak in forests, woodlands, and savannas, especially on mesic, high quality sites. And it is a necessary and often unique disturbance that is needed to sustain oak forests and restore woodlands and savannas today.

There are alternative management practices that can achieve similar outcomes in managing woody structure, but sometimes fire is the most effective tool for achieving specific management objectives, and at times there is no substitute for fire in achieving certain ecological objectives or for restoring ecosystem function. Fire can be compatible in oak management if understood and used properly because oak species have several morphological characteristics that make them well adapted to fire, and these can be exploited to improve oak regeneration success and set it on course to rise to dominance in mature stands. Nonetheless, prescribed fire still has the potential to do damage to trees and the forest if misapplied or used at the wrong stage of stand development. The extent of damage that develops in forests after fire depends on the use of fire in the silvicultural system, and ultimately management goals. It is important to time fire use and control its severity by managing fire intensity and applying it judiciously when it is appropriate given stand structure, composition, and desired stand developmental trajectory. It is imperative to know what the positive and negative consequences are when using fire to sustain oak ecosystems. Fire can provide many ecological benefits; it can also cause much damage and value loss. Wise decisions on fire use derive from knowledge of fire effects on the array of biological, ecological, economic, environmental, and social values, goods and services that come from oak ecosystems.

Small diameter trees that survive being burned can only have small wounds, because if they had large wounds they would be completely girdled and suffer top-kill or mortality. If they are in a dominant competitive position and are vigorous, they can heal quickly, preventing fungal infection and rapidly compartmentalizing the injured tissue. If the damage is to sprouting species such as the oaks, then sprouts following top-kill are free of injury and have room to grow, at least temporarily. Large diameter trees are harder to scar by fire due to their thicker bark. Should they be scarred, these trees are merchantable and may be harvested to limit wood decaying fungi from causing much volume or value loss. Fire scars on the lower end of the butt log are often outside the scaling cylinder and therefore do not affect product recovery or value. It is pole and small sawtimber-sized trees that are at greatest risk of sustaining large scars and remaining in the stand long enough to develop substantial decay. In oak forests and woodlands, prescribed fire is most useful to prepare for and manage regeneration of desirable species. It can be used without causing considerable loss in stand volume or value when incorporated as part of an even-aged silvicultural system. Intermediate-aged stands are at high risk to fire injury and damage; alternatives to fire are preferred for managing stand composition, growth, and quality in these stands. In any case, individual large-diameter trees are at risk of fire damage if the intention is to retain them for the long-term and they are subjected to high-intensity fires. We can manage the timing and application of fire, fuels, and hence fire intensity and duration to minimize the risk of fire damage and mortality.

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RESEARCH BRIEF

Fire damage effects on red oak timber product value

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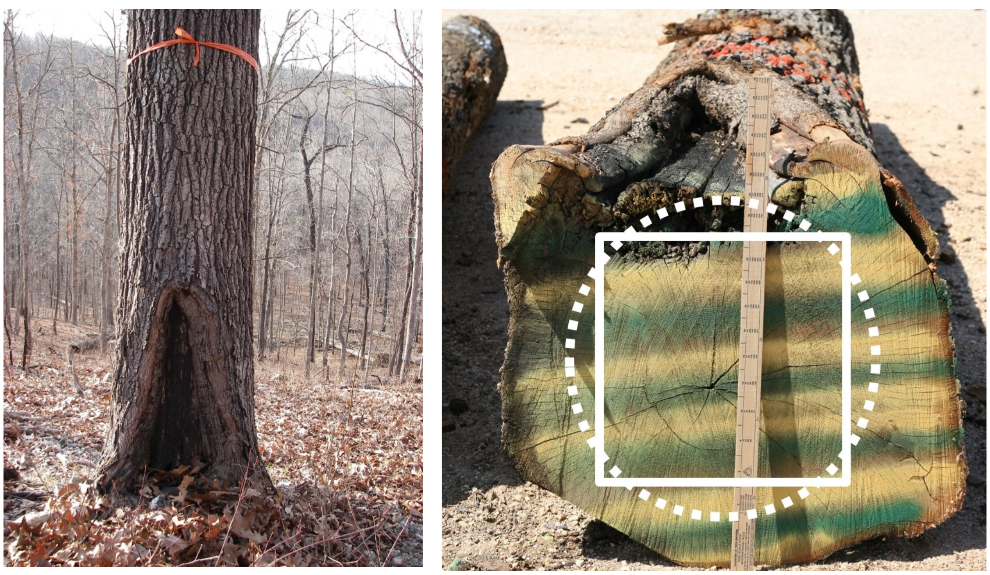
MANAGEMENT IMPLICATIONS

- For red oak sawlogs, most value loss is due to lumber grade changes, not volume loss.
- Expect minimal value loss for red oak sawlogs with fire damage less than 20 inches tall.
- Regardless of fire-scar size, red oak sawlogs harvested within 5 years of injury will have little or no value loss.

In this study, researchers sought to determine how timber value was affected by fire damage to the boles of saw-log size trees. The lowest logs of fire-injured red oaks were harvested and milled into dimensional lumber. Value losses due to fire injuries were tracked through the lumber grading and valuation processes.

The economic loss due to fire-caused injuries (i.e., fire scars) was measured in terms of volume and value in the butt logs (only) of 88 red oak (*Quercus velutina, Q. rubra, and Q. coccinea*) trees harvested from prescribed fire units in southern Missouri. Fire scar dimensions and tree sizes (diameter at breast height (DBH)) were measured prior to tree harvest. Trees with varying diameter, external fire damage, and fire-scar residence time (time between fire damage occurrence and tree harvest) were selected. DBH ranged from 9.5 – 24.8 inches; fire-scar heights ranged from 6 to 154 inches; and fire-scar residence time was a maximum of 14, minimum 2 years. The number of logs above the butt log (upper logs) were tallied and the small end diameter measured. Lumber grade changes and volume losses due to fire-related injuries were tracked on individual boards (n=1298, 7754 board feet). Lumber values were assigned using rough, green lumber values reported by the Hardwood Market Report (April, 2011).



Fire-scarred tree pre- and post-harvest. The dotted circle on the base of the log depicts (to scale) the log's small end diameter. The solid square shows the portion of the round log that is utilized when manufacturing rectangular dimensional lumber. Though this tree appeared heavily defected while standing, its butt log value loss was 8.0%, and its volume loss was 2.8%, with much of the fire-injury defect removed during the milling process. For the whole tree, value loss was 4.4% if upper logs are considered. Photos: Joe Marschall

Overall, value and volume losses were low. Volume loss per fire-scarred log averaged 3.9%, with the value loss average per butt log at 10.3%. The average value loss decreased to 7.1% if estimated values for the upper logs were considered. A large amount of fire-caused defect was removed incidentally during the milling process (see figure). Statistical models were developed that predict log value loss from tree size, fire scar size, and fire-scar residence time. A reference table (next page) was developed to estimate value loss per butt log from tree size (DBH) and fire-scar height and depth. Depending on fire-scar height, annual value loss is estimated to range from 0.5% to 1.3%. For example, a fire scar 40 inches in height is expected to lead to about 10.5% value loss to the butt log if the tree is harvested 14 years after the fire damage occurred.

Trees that were mid-sized (i.e., pole size) when injured were most likely to experience higher value loss, while trees that were small or large in diameter at

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time of injury typically experienced little or no value loss. If fire damage is less than 20 inches in height and/or less than 20 percent basal circumference is injured, then little value loss occurred over 14 years. If these thresholds were exceeded, then value loss was likely. Regardless of fire-scar size, value loss was very low if trees were harvested within five years after fire damage.

Study authors note that Brose and Van Lear (1999) found that implementing relatively simple practices (i.e., directional felling and lopping of excessive fuels near crop trees) in a shelterwood harvest accompanied by prescribed fire can minimize damage to residual trees, indicating that fire-scar heights, and timber quality losses can be effectively minimized.

The findings from the study summarized here are applicable only for red oak trees which are at least 8 inches DBH at time of fire damage and a log grade typical for dimensional lumber utilization (i.e., 'sawlogs') as opposed to higher value products such as veneer or staves, and with fire-scar residence times not greater than 14 years.

FOR FURTHER READING

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Fire-scar height x fire-scar depth (inches)	DBH (inches)													
	10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	2	2	2	1	1	1	1	1	1	1	1	1	1	1
30	5	4	4	3	3	3	2	2	2	2	2	2	2	1
50	8	7	6	5	5	4	4	3	3	3	3	2	2	2
70	11	10	8	7	6	6	5	4	4	4	3	3	3	3
90	15	12	10	9	8	7	6	6	5	5	4	4	4	3
110	18	15	13	11	10	8	7	7	6	5	5	5	4	4
130	21	17	15	13	11	10	9	8	7	6	6	5	5	5
150	24	20	17	15	13	11	10	9	8	7	7	6	6	5
170	27	23	19	17	14	13	11	10	9	8	7	7	6	6
190	30	25	21	18	16	14	13	11	10	9	8	8	7	6
210	33	28	24	20	18	16	14	12	11	10	9	8	8	7
230	36	30	26	22	19	17	15	13	12	11	10	9	8	8
250	40	33	28	24	21	18	16	15	13	12	11	10	9	8
270	43	36	30	26	23	20	18	16	14	13	12	11	10	9
290	46	38	32	28	24	21	19	17	15	14	12	11	10	10
310	49	41	35	30	26	23	20	18	16	15	13	12	11	10
330	52	43	37	32	28	24	21	19	17	15	14	13	12	11
350	55	46	39	34	29	26	23	20	18	16	15	14	12	11
370	58	49	41	35	31	27	24	21	19	17	16	14	13	12
390	61	51	43	37	32	28	25	22	20	18	16	15	14	13
410	64	54	46	39	34	30	26	24	21	19	17	16	14	13
430	68	56	48	41	36	31	28	25	22	20	18	17	15	14
450	71	59	50	43	37	33	29	26	23	21	19	17	16	15
470	74	62	52	45	39	34	30	27	24	22	20	18	16	15
490	77	64	54	47	41	36	31	28	25	23	21	19	17	16

Percent value loss on standing timber per butt log, based on fire-scar measurements and tree diameter.

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