

# Use of Prescribed Fire in Rangeland Management

A Training Manual

For a Short Course Held  
February 20<sup>th</sup>-26<sup>th</sup> 2005  
**Yabelo, Ethiopia**

Compiled and Edited by:  
Mr. Eric M. LaMalfa and Dr. Layne Coppock  
Utah State University, College of Natural Resources  
Logan, Utah 84322 USA



*Global Livestock CRSP*



**USAID**  
FROM THE AMERICAN PEOPLE



## **Acknowledgement**

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## **Course Outcomes**

- **Learn about the role of fire in rangeland ecosystems.**
- **Learn how to plan and implement a prescribed fire.**
- **Learn how to monitor fire effects to assist management decision-making.**
- **Make progress towards conceptualizing a community-based, fire management program on the Borana Plateau.**





**Provisional Course Schedule (PARIMA/GL-CRSP)  
Use of Prescribed Fire in Rangeland Management  
February 20-26, 2005  
Yabelo, Ethiopia**

**Sunday February 20**

5:00-6:30 PM: Check-in (meet at SORDU Compound)

6:30-7:30 PM: Introductions; course overview; changing views of fire in the USA

7:30-8:30 PM: Borana experts speak on the history of fire and traditional methods of fire use in the southern rangelands

8:30-10:30 PM: Dinner and welcome social

**Monday February 21**

8:00-9:00 AM: Range management goals and objectives

9:00-10:00 AM: Rangeland monitoring (Qualitative/ Management)

10:00-10:15 AM: Coffee break

10:15-12:30 PM: Rangeland monitoring (Quantitative/ Research)

12:30-1:30 PM: Lunch

1:30-5:00 PM: Rangeland monitoring exercise (site to be determined)

5:30-7:00 PM: Dinner

**Tuesday February 22**

8:00-10:00 AM: Elements of fire behavior

10:00-10:15 AM: Coffee break

10:15-11:15 AM: Monitoring fire effects and fire weather and use of local weather data

11:30-12:30 PM: Fire prescriptions and planning

12:30-1:30 PM: Lunch

1:30-2:00 PM: Travel to Didahara (30 km)

2:00-5:30 PM: Fire prescription review, practice a pilot fire, and prepare site for main prescribed fire at Didahara

5:30-6:00 PM: Travel back to Yabelo

6:30-8:00 PM: Dinner

### **Wednesday February 23**

8:00-9:00 AM: Predicting fire behavior

9:00-10:00 AM: Fire ignition techniques

10:00-10:15 AM: Coffee break

10:15-12:00 AM: Fire safety

12:00-1:00 PM: Lunch

1:00-1:30 PM: Travel to Didahara (30 km)

1:30-6:00 PM: Conduct main prescribed fire at Didahara

6:00-6:30 PM: Travel back to Yabelo

7:00-8:30 PM: Dinner

### **Thursday February 24**

8:00-9:00 AM: Fire Suppression/ Safety

9:00-10:00 AM: Managing a prescribed fire/ fire scenarios

10:00-10:15 AM: Coffee break

10:15-11:15 AM: Post-fire review and discussion (Didahara)

10:45-12:00 AM: Group assignment for fire-prescription

12:00-1:00 PM: Lunch (and group photo)

1:00-2:00 PM: Travel to Alona (60 km)

2:00-5:00 PM: Fire prescription review, practice a pilot fire, and prepare site for main prescribed fire at Alona

5:00-6:00 PM: Travel back to Yabelo

6:30-8:00 PM: Dinner

### **Friday February 25**

8:00-10:00 AM: Rangeland ecology

10:00-10:15 AM: Coffee break

10:15-12:00 AM: Rangeland ecology and the Borana cattle cycle

12:00-1:00 PM: Lunch

1:00-2:00 PM: Travel to Alona (60 km)

2:00-6:00 PM: Conduct main prescribed fire at Alona

6:00-7:00 PM: Travel back to Yabelo

7:30-8:30 PM: Dinner

### **Saturday February 26**

8:00-10:00 AM: Course review

10:00-10:15 AM: Coffee break

10:15-12:00 AM: Course review

12:00-1:00 PM: Lunch

1:00-2:00 PM: Travel to Didahara and Alona (60 km)

2:00-5:00 PM: Post-fire assessments at Didahara and Alona

5:00-6:00 PM: Travel back to Yabelo

6:30-8:00 PM: Dinner

**END OF COURSE**



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Unit 1  
Changing Views on Fire  
Management





### Fire as a tool in rangelands



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### Fire's ecological role

Disturbance is "any event that disrupts the ecosystem, vegetation community, or population structure and changes the physical environment"

- Grazing
- Drought
- Plow /Agriculture
- Fire

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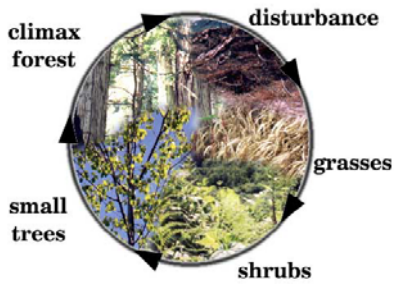
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### Succession



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## Human fire History

- Fire occurred periodically due to lightning, dry conditions, etc.
- People have altered the North American landscape for 12,000yrs. (Africa?)
  - Took advantage of “natural” fire
  - Also capable of very precise controlled burns
  - Resulted in altered vegetation patterns

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Fire: “a natural factor that is as important as wind or water in determining the function of many ecosystems”

*Chapter 12 Fire*

**Table 12.1** Fire Frequencies from Selected Vegetation Types in North America

Vegetation Type and Location	Record Type and Period	Fire Frequency (years)	Reference
Prairie, Missouri	—	1	Kucera and Ehrenreich (1962)
Long-leaf pine and blue stem ranges, southeast U.S.	—	3	Duvall and Whittaker (1964)
Mixed conifers, California	Fire scars on trees (1581–present)	7–9	Wagner (1961)
Ponderosa pine, Arizona	Fire scars on trees (1700–present)	5–12	Weaver (1951)
Mixed forest, Minnesota	Lake sediments (1000 years)	60–70	Swain (1973)
Boreal conifers, Northwest Territories	Fire report records (1966–1972)	110	Johnson and Rowe (1975)
Mixed forest, New Brunswick	Fire report records (1920–1975)	230–1000	Wein and Moore (1977)

Source: After Wein, 1978. Copyright Plenum Press. Used with permission.

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## Role of Fire in Landscapes:

- Control disease, insects, parasites
- Open understory
- Increase light/ water reaching the soils
- Favors fire-tolerant species
- Release nutrients back into the soil or sterilize soil

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**Other possible effects...**

- Fisheries: increase water temp & sedimentation, decrease water quality, change water chemistry
- Destroy/create critical habitat
- Invasive plants
- Disease/insect infestations

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**Policy of fire suppression**

- Fire viewed as something to be “controlled”
- Aggressive fire suppression policy in wildland areas since the beginning of the 20<sup>th</sup> century
- Goals of suppression:
  - Protect public/private property
  - Prevent destruction of grasslands
  - Protect fuel resource

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**Results of suppression**

- Decreased forage
- More intense fires
- Spread of invasive/non-native species
- Ecosystem shifts to woody plants

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Why do we use prescribed fire?

- Range forage
- Habitat improvement for wildlife
- Fire prevention
- Improve visibility
- Restore *natural* or *historic* landscape
  - How do we define what is “natural”?

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Take home message

- Fire is a disturbance mechanism
- Role of fire in Rangelands
- Evolution of fire policy
- Plant adaptations to fire
- Fire is not simply good or bad
- Economic concerns may way as heavily as “science” in making decisions

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Questions?

- What are the rangeland issues in your home?
- How do people in your community think about fire?
- Is fire a tool that can improve your home rangelands?
- Is fire a safe tool your community can use?

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# Unit 2

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## Range Monitoring



### Management Goals and Objectives



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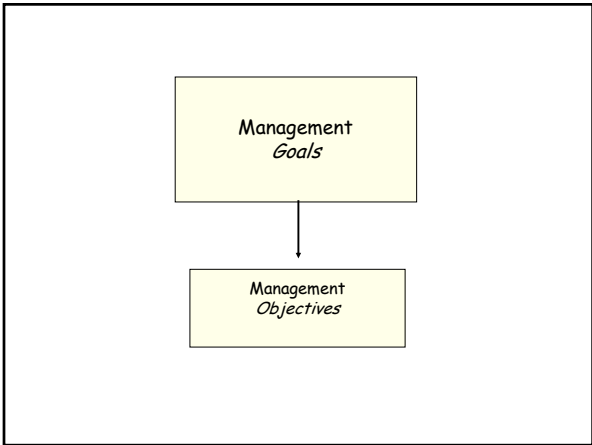
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### Good Goals

- **Informed** by both resource users and professionals in collaboration.
- A **General** philosophical statement about what the group wants to achieve.

*Example "Sustainable rangeland livestock production system"*

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### Good Objectives

- Specific
- Measurable
- Achievable
- Related
- Timeframes



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### Components of an Objective

- Species or indicator
- Location
- Attribute (e.g., size, density, cover)
- Action (increase, decrease, maintain)
- Quantity (degree of change, or range)
- Time frame

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### Example



**Goal-** Sustain the Longnose bat in Arizona USA.

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### Qualitative Objectives

- Reduce cover of encroaching woody species
- Promote health of grassland native species especially the *Agave* spp.
- Reduce non-native plant species.

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### Quantitative Objectives

- Top-kill at least 10% woody vegetation (up to 100% if possible).
- Top-kill less than 30% of the *Agave* spp.
- Reduce non-native plant species cover by 50%.

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### Qualitative vs. Quantitative Monitoring

*The type of objectives will determine the type of monitoring (data collection).*

**Rangeland managers** use more qualitative monitoring to document changes happening across large landscapes where many different treatments and site types occur.

**Researchers** use more quantitative monitoring which provides "statistical significance" associated with a controlled experiment. This is very intensive process used for answering questions to better inform management.

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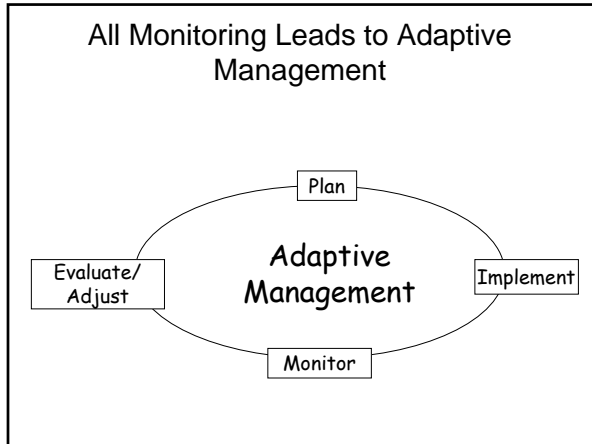
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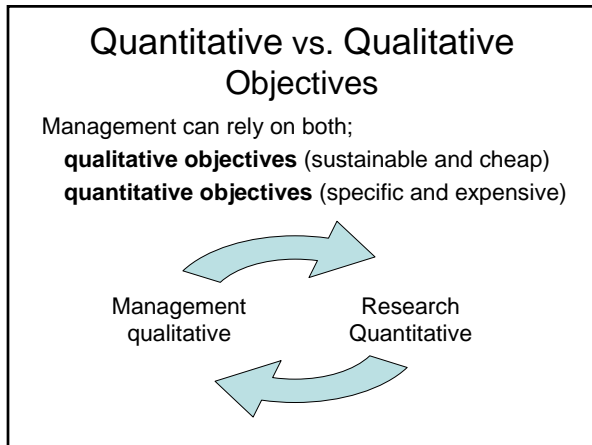
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Community Based Decisions & Discussion

- **Management goals** can be defined by professionals and communities working together.
- Local leaders and government agencies work together to set **specific objectives** for individual sites to reach these goals.
- Each site within a region may require very different objectives to reach a common goal. Communities must agree to manage wisely into the future (partnership).
- **What, Where, Why?**

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# DEVELOPMENT OF OBJECTIVES

By Dr. Tom Zimmerman

## Introduction

Management is the process of anticipating the future, setting objectives, implementing an action, achieving an output, and performing an evaluation comparing the output to the objective. Management is not possible without setting objectives. Clear and easily communicated objectives facilitate the management process. In land management programs, the desired outcome of management actions is expressed as management objectives. Objectives represent an important component of all land management programs and are the single most important factor driving all management actions.

## Goals and Objectives

In land management, both goals and objectives are important. Goals are primary and basic products of the long range management plans. These goals are commonly referred to as land use decisions. **Goals** are relatively short statements that discuss what the public lands are to be used for and where the uses will occur. Each statement addresses a land use, but is not limited to the principal or major use. **Objectives** are a necessary component of the planning process; they provide a bridge between goals and the implementation phase. Objectives describe what procedures will be used and when actions will be completed. During the planning of fire management projects (treatments), objectives are formulated and used as the basis for development of a prescribed fire plan.

## Qualities of Good Objectives

Fire management objectives must be made up of certain attributes or they will not convey the necessary guidance. Good objectives must be informative and SMART.

**S - Specific** - what will be accomplished, using limiting factors, and identifying the range of acceptable change from the present to the proposed condition.

**M - Measurable** - the present and proposed condition must be quantifiable and measurable.

**A - Achievable** - can be achieved within a designated time period.

**R - Related/Relevant** - related in all instances to the land use plan goals and relevant to current fire management practices.

**T - Timeframe** - objectives must be measured after some time has passed and must include a definite timeframe for achievement, monitoring, and evaluation.

## Kinds of Objectives

**Land Management Decisions (goals).** These are broad statements that deal with large areas over long time periods (e.g., 10 years). Land management decisions establish resource condition objectives; the allowable, limited, or excluded uses for an area (Grazing use allocations) and the terms and conditions for such use; and management actions that will be taken to accomplish multiple use goals.

**Resource management objectives.** Resource management objectives identify the changes in water, soil, air, or vegetation from the present to proposed conditions. Resource objectives can also describe an existing resource condition that should be maintained.

**Treatment objectives.** These are very well-defined statements that describe what a treatment must accomplish in order to meet a stated resource management objective. This type of objective is site-specific and must utilize the SMART concept.

Any statement that is an objective must identify the change from present conditions to the proposed conditions (the changes that are planned) and the limiting factors.

## How Objectives Relate to Project Inventory, Development, Implementation, Monitoring, and Evaluation

Objectives are an important part of management actions and are prerequisite to sound land and resource management. Objectives not only drive the planning system, they also drive the full spectrum of project implementation, monitoring, and evaluation. During the fire planning process, for example, the planner uses resource management objectives (standards) as guidance to determine what fire management responses and activities are necessary. These standards then provide guidance in determining what and how much information should be collected prior to and during project implementation. At this point, knowledge of fire effects becomes a necessary part of the planning process. Fire effects information helps to determine what will be done, how many resources are needed, and what should be evaluated to ensure efficient accomplishment of the workload.

**Resource and Fire Treatment Objectives**  
**BLM Prescribed Fire Manual**  
**2000**

The Prescribed Fire Planning process is initiated by guidance established in land management plans. A land management plan may include a list of general goals (Grazing, wildlife, fuel wood) that deal with large areas over long time periods. While a prescribed fire plan may be mentioned in land use plans, specific objectives that define prescribed fire use in an ecological site are most often developed in the prescribed fire plans. During the prescribed fire planning process, the interdisciplinary team refines objectives into very site-specific land management objectives that describe the longer term desired changes in site conditions, such as increased plant productivity, altered species composition, or increased off-site water yield. These land management objectives describe fire effects that will occur as a result of the changes in the environment caused by the prescribed fire.

Prescribed fire treatment objectives describe immediate fire effects, (e.g., fuel consumption, plant mortality, soil heating, and burn pattern). These are the effects which the fire must create to achieve the site-specific land management objectives. Prescribed fires are conducted under selected weather and fuel moisture conditions to create fire behavior characteristics and residual fuel burnout that are most likely to produce these direct and immediate effects of the fire.

***Both Land Management and fire treatment objectives need to be specific, measurable, achievable, related to the land use plan goals, and have definite timeframes for achievement, monitoring, and evaluation.*** The timeframe for achievement of resource objectives is usually two or three years. The timeframe for fire treatment objectives is immediate because they are achieved during the course of the prescribed fire. The following section provides a series of examples that show derivation of fire treatment objectives from land management plan goals, activity plan objectives, and prescribed fire resource objectives.

1. Forb production:

- a. Land Management Plan goal Provide quality habitat to support a diversity of wildlife species.
- b. Activity plan resource objective. Improve mule deer spring range in mountain big sagebrush communities in the Big Creek watershed.
- c. Prescribed fire resource objectives. Increase the production of forbs from 100 pounds per acre (air-dried weight) to 200 to 300 pounds per acre by the end of the third full growing season after the prescribed fire by removing competition from sagebrush. Leave 30 to 40 percent of the area unburned.
- d. Fire treatment objective. Kill 100 percent of mountain big sagebrush by burning with enough fireline intensity to kill the sagebrush and to remove fine branchwood less than 1/4 inch in diameter. Burn in a mosaic pattern leaving 30 to 40 percent of the area unburned in patches 25 acres or larger.

2. Browse enhancement:

- a. Land Management Plan goal Provide quality habitat to support a diversity of wildlife species.
- b. Activity plan resource objective. Improve mule deer winter range in mountain shrub communities in the Big Creek watershed.
- c. Prescribed fire resource objectives. Increase the production of fine twigs

by inducing resprouting in serviceberry, with 90 percent plant survival after the second growing season. Increase browse availability by removing old, nonproductive branches. Leave at least 20 percent of the area unburned in a mosaic pattern.

- d. Fire treatment objectives. Burn with high enough fireline intensity to remove serviceberry branchwood less than ½ inch in diameter on 90 percent of the plants. Sustain no more than 10 percent mortality of mature serviceberry plants. Burn in a mosaic pattern, leaving at least 20 percent of the area unburned in 10 to 25 acre patches.

### 3. Watershed restoration:

- a. Land Management Plan goal. Restore the Big Creek watershed.
- b. Activity plan resource objective. Increase water yield and decrease siltation into Big Creek and its reservoir.
- c. Prescribed fire resource objectives. Increase July stream flow in Big Creek from the 20-year average of 100 cfs to a five-year average of 150 to 200 cfs within five years by removing juniper cover that has invaded into mountain big sagebrush communities. Increase the canopy cover of grasses and forbs from 10 percent to 20 to 40 percent within three growing seasons.
- d. Fire treatment objectives. Generate adequate flame length to kill at least 80 percent of the junipers that are less than 10 feet tall, and achieve 30 to 40 percent mortality of trees taller than 10 feet. Leave at least 20 percent of the area unburned in a mosaic pattern with unburned patches of 20 to 50 acres. Sustain less than 10 percent mortality of bunch grasses.

After reviewing the fire treatment objectives that the Fuels Management Specialist believes are possible on this site given the fuels, the interdisciplinary team may decide that the juniper mortality after one prescribed fire is not adequate to meet resource objectives. It may be determined that manual cutting of taller trees is necessary before the prescribed fire, or that a second prescribed fire treatment is needed after the understory has recovered to a more productive state with greater canopy cover.

### 4. Hazardous fuels reduction

The intent of a treatment can be a first-order fire effect of hazardous fuels reduction, identified in the Fire Management Plan. There may be other fire effects worth including as objectives to ensure that fuels are managed without harming other desirable site properties.

- a. Land Management Plan goal. Manage fuels in the wildland/urban interface.
- b. Fire Management Plan objective. Manage ponderosa pine stand structure in the area of BLM ownership adjacent to Newtown to decrease potential for crown fire, and decrease both intensity and severity of surface fires.
- c. Treatment objectives. Kill 70-90 percent of understory Douglas fir with stem diameter of less than two inches. Consume 70-90 percent of down-and-dead woody fuels in the zero to-three-inch size class. Remove 30-50 percent of the duff, leaving some duff cover on 60 percent of the area. Kill no more than 10 percent of trees larger than 12 inches in diameter.

## Qualitative Monitoring

Photographs and Descriptions

*Qualitative monitoring is paying attention to changes on the land and recording what you see.*

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## Why Qualitative Monitoring

- Useful – it helps us “see” changes in the landscape over long periods of time and facilitating adaptive management.
- Sustainable – It requires little training, thus, when a person moves to a new area it is easy to pick up where the previous person left off.
- Quick – a manager can inventory much of the region without missing other duties (less expensive).

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## Qualitative Monitoring



- Three Steps;
  - Take a Photo
  - Record your interpretation
  - File it for later reference
    - Repeat the process

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### Location of Photo-points

- Use an area containing the attributes of most interest (e.g. shrub thicket).
- Use areas that are easily accessible.
- Representative views of the whole area
  - May be more than one site types
  - There may be a elevation gradient
  - Number of Photos?
    - time/ money/ repeatability



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### Comparison photos

- Before and after treatment
  - Photo must be taken from the same point as before
- Treated vs. untreated
  - Same; soils, topography, and history



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### Photography Standards

- Landmarks for reference
  - horizon line, boulders, roads, etc.
- Photo board
  - Record the location and date
- Reference pole
  - 1 meter pole for size reference

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**Site Evaluation and Interpretation**  
Focus on the attributes of interest

- Site type and History
  - soils, plant community
  - fire, fuel wood cutting, grazing, other treatments
- Plant type and condition
  - weeds, forage, establishing, mortality
  - possible reasons
    - drought, grazing, fire, insects
- Management concerns
  - erosion, woody plants, weeds, fuel, forage?

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**Record Basic Information**

- Photographer/ Observer/ Season/ Date
- GPS the Location
- Draw a map of the surroundings
- Give directions for relocation
- Record the direction of the image (looking north)
- Mark the point (if possible)
  - Rock Pile
  - Stake




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### Organization of Reports

- Keep all information in a central known location
  - File cabinet, computer, or both
  - Make a master list and map of all sites
- File the documents by region
  - Site (Alona)
    - Location (Prescribed Fire Unit 2005)
      - Photo-point # 1,2,3,etc..
- Add the information gathered in following years to the existing files.

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### Follow up

- Organize the photos
- Take the pictures and evaluate in following years during the same season
  - Record the days or weeks since rains begin.
  - Record the season
  - Record the day of the year
  - Take note of differences

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### Discussion Questions ?

- Where will files be kept?
- How often will sites be visited?
- How many pictures and sites can be visited in a year at OARI (time and money)?
- Photos, Slides, or Digital?
- What season will Photos be taken in (objectives)?



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# REPORT

## Management/ Qualitative Monitoring Evaluation

Region:
Area:
Site Name/ number:
GPS Location:
Marker (yes/ no):
Date:
Observers/ Photographers:
Direction of Photo:

Map
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Directions:




## Quantitative Monitoring Research and Analysis

*Quantitative data collection can be intensive and expensive, it must be based on a defined research question*

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### When to Use Quantitative Monitoring Research?

- Testing ideas about what change is happening on the land and why.
- Comparing different treatments or other management techniques to determine the “best” way to manage the land.
- To measure (in detail) the amount of change in an attribute (and have reasonable control).

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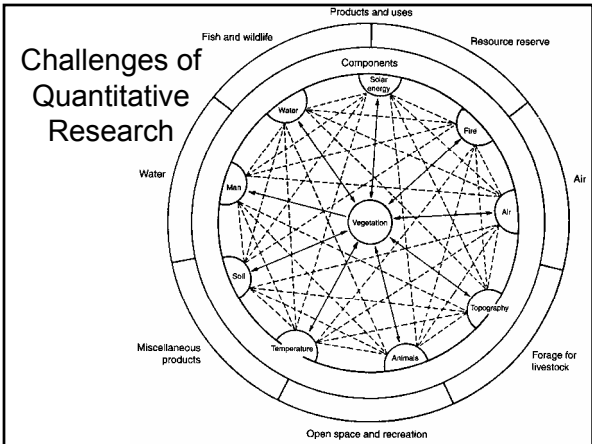
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### Eight Steps to Quantitative Monitoring for Research

1. Define the purpose, objective, or question
2. Select the attribute to measure
3. Select the area to monitor
4. Choose appropriate monitoring method
  - cover, density, mortality, etc..
5. Locate plots without bias (randomly)
6. Obtain the data
7. Analyze the data
8. Interpret the results

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### Research Design

- Number of plots can be high
- Treatment and control sites
  - Randomization & Replication
- Standards for sampling must be decided
  - Based on variability
- Analysis methods must be pre-defined
  - Statistics

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### Quantitative Research Methods and Examples

- Tick Monitoring
- Vegetation Monitoring
  - Woody plants
  - Herbaceous plants
- Fire Behavior Monitoring?

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### Quantitative Terminology

**Site-** The location of interest (treatment and control), where monitoring will occur.

**Transect-** a sample area in the form of a long continuous strip.

**Belt transect** – Measuring attributes of interest which occur in a wide “belt” along a transect.

**Line transect** – Measuring or counting attributes beneath a transect or along the transect in frames.

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### Quantitative Terminology

**Plot** – a “sub-sample” of the vegetation occurring along a transect or within a site.

**Plot Frame** – A frame with a given size used to measure attributes along a line transect.

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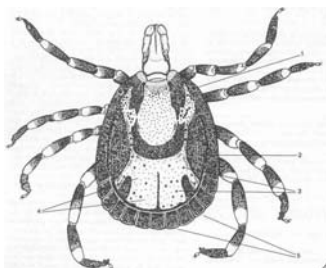
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### Tick Monitoring



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### Tick Drag Monitoring "Density"

#### Three Steps



- 1) Drag a sheet along a belt transect avoiding shrubs and thorns.
- 2) Count the number of ticks on the sheet .
- 3) Estimate transect length (double pace or tape measure).
- 4). Calculate the number of ticks per hectare.

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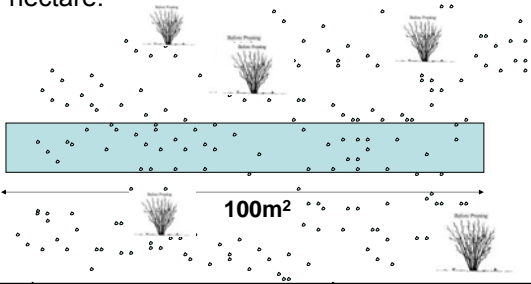
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### Density (Ticks)

#### Belt Transect

- **Density** – The number of individuals per hectare.



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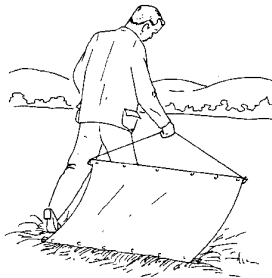
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### Tick Drag Method

#### Standard Sampling

- Muslin Fabric (Specific width)
- Wood frame
- Weight in pockets
- Tweezers
- Tape measure
- Data sheet



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### Tick Drag Method Standard Sampling

- Location affects tick habitat
  - Vegetation type
  - Humidity (shade)
  - Animal traffic (near trails or holding pens)
- Will not be accurate if
  - Temperature is  $< 10^{\circ}\text{C}$
  - Vegetation is wet
  - Season is different




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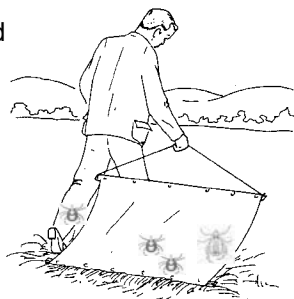
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### Tick Drag Method Standard Sampling

Repeat monitoring and site comparisons (treatment vs. control) must be measured using the same methods.




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### Ticks/ hectare Analysis

- Drag the sheet (specific width) for a specific distance and calculate area.
- Count the number of ticks on the sheet.
- Determine Density
  - There are 10,000 m<sup>2</sup> in each 1 ha.
  - Calculate,  

$$[\# \text{ ticks} / \text{Transect Area (m}^2)] \times 10,000 \text{ m}^2$$

$$= \# \text{ of Ticks/ hectare}$$




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### Tick Monitoring Difficulties

- Sample a few transects to estimate variation in ticks per transect.
- What number of ticks can be counted easily?
- The number of transects needed for precise estimation increases as variation among transects increases, or as variation between treatments (fire vs. control) decreases.
- Is a qualitative method or interpretation better for your program?
- (how? why?)

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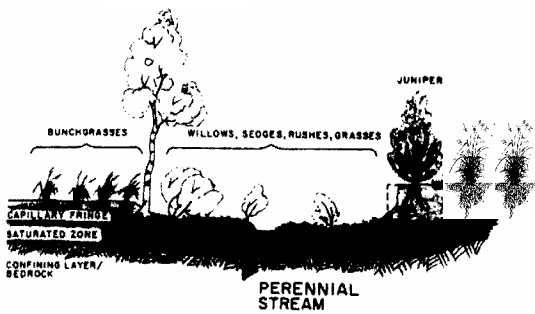
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### Vegetation Monitoring




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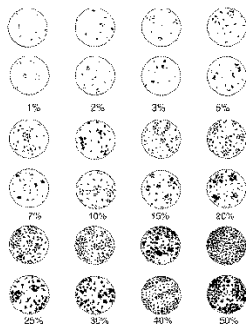
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### Difficulties in Vegetation Attributes

What to measure?

- **Cover** →
- Density
- Biomass




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### Vegetation Attributes

we will focus on these questions

- **Cover**- how much of the ground is “covered” by valuable forage vs. noxious weeds?
- **Density**- How many shrubs per hectare are on a site? How many trees are there per hectare?
  - **Mortality**- What percentage of small shrubs were killed by last years fire?

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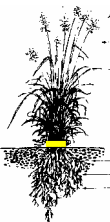
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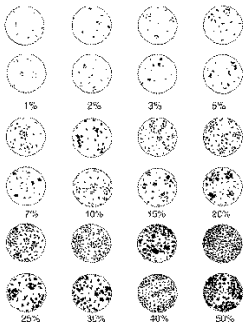
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### % Basal Cover (Herbaceous)

0.25m<sup>2</sup> frame

- **Basal Cover**- the soil surface area occupied by the base of the plant.





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### % Basal Cover (Herbaceous)

Four steps

1. Begin with a random start between 1-10 meters along the transect.
2. Place the plot frame at even intervals along the transect (e.g. every 10 meters).
3. Estimate the % cover of defined categories within the plot frame (forage, weeds, bare ground, etc.).
4. Calculate the average % basal cover for the transect.




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### % Basal Cover



- For each transect add the estimated % cover together for each plant type.
- Divide the total for each category by the number of plot frames along the transect.
- Determine if you need more transects.
  - Are most transect means similar or is there high variability?
  - If highly variable you may need more transects (statistics).

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### Cover Estimation

- Frame size cannot become too large because estimates become less accurate/ repeatable.
- 0.25 m<sup>2</sup> frame is the largest size suitable for visual cover estimates.
- 0.10 m<sup>2</sup> Daubenmire frame is most used to estimate cover classes.




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### Cover (Herbaceous) Daubenmire frame

- Cover classes
- + <0.6% (trace)
  - 1 0-5%
  - 2 5-25%
  - 3 25-50%
  - 4 50-75%
  - 5 75-95%
  - 6 95-100%




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### Cover categories

<p><u>Simple</u></p> <ul style="list-style-type: none"> <li>• Total grass</li> <li>• Total forbs</li> <li>• Bare ground</li> </ul>	<p><u>Complex</u></p> <ul style="list-style-type: none"> <li>• Perennial grass</li> <li>• Annual grass</li> <li>• Forbs</li> <li>• Noxious weeds</li> <li>• Bare ground</li> <li>• By species</li> </ul>
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### Cover Sampling Problems

- Large numbers of samples (transects or plots) are required for highly variable sites.
- Time intensive process
- We are “measuring” an estimated attribute by using our eyes.
  - Each observer may estimate differently
  - Bias – we often see what we want to or expect?




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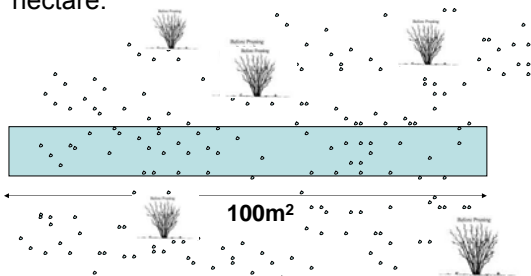
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### Density (woody plants) Belt Transect

- **Density** – The number of individuals per hectare.




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### Density (woody plants)

Three steps

- 1) Carry a 1 meter stick perpendicular to a belt transect counting the number of shrubs rooted within the belt (size class).
- 2) Calculate the number of shrubs per hectare (two person/ team).
- 3) More transects (or longer) if variability is high.
- 4) Larger plants require larger transects.

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### % Mortality (woody plants)

Belt Transect

*To estimate % mortality take the density method one step further.*

- Mark the location of the transect using a permanent stake (metal).
- Return to the location after the treated vegetation has resumed growth.
- Measure the belt transect again noting live, dead, and new sprout categories.
- For accurate estimation > 350 plants/ site total are required (statistics).

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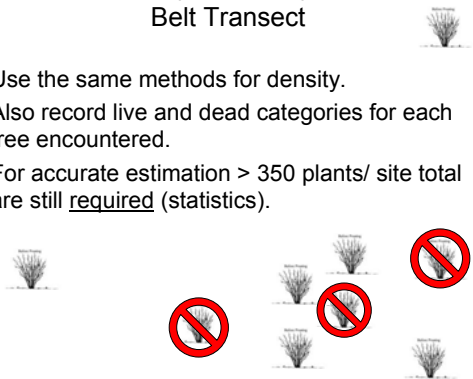
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### % Mortality (Woody Plants)

Belt Transect

- Use the same methods for density.
- Also record live and dead categories for each tree encountered.
- For accurate estimation > 350 plants/ site total are still required (statistics).



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## General Density Rules

- The number of transects needed are related to variation of transect means.
- Try to get all means within 20% of each other.
- More variation = more or longer transects.
- Hopefully 3-6 transects per site.

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## Conclusion

- Quantitative research methods can also be used to get an idea for describing the attributes we see in qualitative monitoring. Detailed, controlled research is best done on-station (e.g. Did Tayura Ranch)
- Qualitative monitoring sometimes leads us towards questions that can only be answered using quantitative research methods.

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## Discussion

- What are the institutional and seasonal constraints?
  - Qualitative: 30 sites in 5 days
  - Quantitative: 30 sites in 30+ days
- What attributes should we measure/ observe?
- Agencies in the US primarily rely on qualitative information for management purposes. The same agencies sometimes collaborate with Academic institutions using quantitative approaches. Why would they do this?

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### Concept and definition

Plant cover is one of three terms used to describe, or indicate, the amount of each species or the amount of vegetation present on a site. [The others are density and biomass.] As plants grow, their foliage tends to cover the ground as the leaves spread out to capture the available light. In a literal definition, "cover" is the relative amount of the ground surface that is covered by a type of vegetation or by a particular plant species. Conceptually we can envisage cover as though we were viewing the vegetation from above, looking directly down toward the ground and imagining that all the leaves and stems that we see are projected vertically onto the soil surface. Another way of thinking of cover is to imagine that it is the shadow on the ground cast by the plant material under a strong light immediately overhead.

Cover is usually expressed in relative terms, as a percentage. Thus, in the preceding example the plant cover is the percent of the ground surface in shadow. A cover of 4.5 percent means that, on average, 450 cm<sup>2</sup> of every square meter (10,000 cm<sup>2</sup>) is covered by plant material. This means that cover is merely an *index* of the amount of plant material present. For a particular species or vegetation type, higher values of percent cover are generally associated with greater plant biomass, but one must also take into consideration the architecture of the foliage in both vertical and horizontal planes. A species with a basal, rosette leaf structure may have higher cover than a species with dense foliage of erect leaves, but nevertheless be inferior in terms of biomass. You must be careful when interpreting cover data, especially in semi-arid ecosystems.

### Application of cover estimates in range ecology

Cover is generally employed for two objectives in range ecology: to assess vulnerability to soil erosion, and to estimate species composition in the plant community.

The cover of vegetation (and also the cover of leaf and stem litter lying on the ground, no longer connected to living plants) is of direct interest to watershed management. Plant material and litter intercept rain and reduce the erosive effect of raindrop impact. The more the soil surface is covered by plants and litter, the better the soil is protected against erosion. Gravel (in the form of "desert pavement," for example), and cryptogams also provide protection against erosion. From a watershed management point of view, the mix of species in the plant cover is of less importance than the absolute amount of cover afforded by the vegetation and other protective materials.

In contrast, species composition refers to the relative amounts of each species present in a plant community, and is usually expressed as the percent for each species, with the sum total of percent composition values equaling 100. The accuracy with which species composition can be estimated from relative cover values depends on the characteristics of the vegetation being sampled and the particular field method employed.

When many fine-leaved species are growing in a vegetation mixture the cover values of individual species are difficult to determine no matter which method is used. In a comparison among cover methodologies, some methods are more reliable than others. Cover estimations often vary substantially among different observers. Unlike plant biomass, which can be weighed exactly, or plant density which can be derived from an exact count, the "true cover" in a quadrat cannot be known precisely, except by laborious grid-point, charting or pantograph sampling procedures, which at best only approach an approximation of reality.



As a general rule, plant cover is not a very reliable parameter for range analysis, except in special situations, namely, when estimating the cover of shrub or tree canopies, or when estimating the basal cover of bunchgrasses. In this course you will obtain experience estimating cover by visual assessment of quadrats, by measuring shrub canopy diameters, by point-sampling with the step-point method or at points located along a transect tape, and by measuring intercept lengths along a transect. You will discover that it is difficult to estimate cover with reliability, let alone accuracy, except for the special situations mentioned above. And you will discover that there can be great variability among personnel sampling identical locations.

European ecologists have tended to avoid attempts to estimate specific cover values. Instead they have assigned species to cover classes, each class representing a range of cover values. This approach to cover assessment is well suited to general description and classification of vegetation. It is discussed in more detail in the final section of this handout.

The range manager or researcher must choose between a coarse-level cover-class system for assessing cover, designed for general description of vegetation composition, and methods which estimate cover as a continuous variable, but with poor reliability and uncertain accuracy. Fortunately, when the goal is to define species composition, there is less variability among methods in determining *relative* cover than in estimating *absolute* cover. Nevertheless, for determining species composition of a mixed herbaceous community, the instructor for this course recommends the Dry-Weight-Rank method instead of relative cover by any method.

- (3) **Quadrat estimation**, in which the observer examines a quadrat and guesses how much (the %) of the area of the quadrat is covered by vegetation as a whole or by each species present in the quadrat. Categories such as soil, rock and litter can be estimated for percent cover, too, if that is desired. Each species is viewed independently of the others, so that full credit is given to the cover of a species lying partially under the canopy of another species. Once again, the decision of whether to estimate foliage cover or canopy cover must be made in advance, and appropriate sampling rules established.

The percent areas of exposed bare ground and litter not lying under the protection of living plant foliage, nor under a plant canopy, should be recorded separately in order to determine the relative portions of vegetative and non-vegetative cover. Alternatively, one could estimate total vegetation cover in the quadrat as an independent variable. Although, theoretically, the sum of individual species cover values should be equal to or greater than the cover of total vegetation estimated independently, that often fails to occur. The independent estimate of total vegetation cover can be used as a check on the separate estimates of individual species cover. A wide discrepancy between total cover and the sum of species cover values cautions the observer to re-evaluate his data for that quadrat.

Quadrats should be objectively located in the vegetation; often regular or random locations along transect lines is a convenient approach. In this method each quadrat constitutes one sample, so quadrat estimation is easier than previous methods in terms of collecting data from several samples for the calculation of means.

### Cover-class assessment for vegetation classification

The percent cover of individual species is one of the attributes that is used to characterize and classify vegetation into community types. European ecologists have developed standard methodologies that employ a large plot of perhaps 2 x 5 m, or 10 by 20 m, representative of the vegetation type, called a "relevé." Information may be collected from several relevés, each one representing a common variant of one general type of vegetation. Each species present in a relevé is assigned to a cover "class" rather than estimating cover to the nearest percentage point. For example, in the best-known version of this method, devised by Braun-Blanquet (1928), there are 5 classes representing 3 ranges of cover from as small as 4 units of percent (class 1: 1-5% cover), 20 units (class 2: 5-25%) and 25 units of percent (classes 3, 4 and 5: 25-50%, 50-75% and >75% cover, respectively). An American version of this method (Daubenmire 1959) follows Braun-Blanquet's cover classes but adds a class of 95-100% (class 6) at the dominant end of the scale.

One advantage of this method is that a lot of useful and reliable information can be collected in a relatively short time. Another advantage is that the assignment of species to particular cover classes is repeatable among trained observers. This approach to cover assessment is well suited to the general description and classification of vegetation. It is not well suited to quantitative analysis, because (1) the sample size is generally small; (2) we must assume that the true cover values within a class are normally distributed around the midpoint of the class, which is unlikely for a broad class; and (3) the power to discriminate among species is weakened by the tendency for most species to fall into only 2 or 3 classes at the lower end of the scale. Domin and Krajina (1933) tried to resolve the last problem by dividing the 1-50% domain into 7 cover classes instead of 3. A summary of three cover class systems is attached to this handout.

## Example Calculations (Tick Density)

Burned Site				Un-Burned Site			
Transect	Length	Tick #	Ticks/ ha	Transect	Length	Tick #	Ticks/ ha
1	100	30	3000	1	100	7	700
2	70	34	4857	2	100	15	1500
3	100	49	4900	3	200	20	1000
4	100	67	6700	4	100	10	1000
5	70	35	5000	5	70	35	5000
6	50	10	2000	6	50	10	2000
7	10	30	30000	7	10	30	30000
8	100	20	2000	8	100	20	2000
9	100	54	5400	9	100	21	2100
10	100	65	6500	10	100	20	2000
11	200	53	2650	11	70	11	1571
12	100	10	1000	12	50	10	2000
13	70	20	2857	13	10	20	20000
14	50	60	12000	14	100	12	1200
15	10	20	20000	15	100	20	2000
16	100	30	3000	16	100	8	125000
Mean <b>6992</b>				Mean <b>12442</b>			

What does this mean if we collect this information before the burn?

What about after the burn?

## (Shrub Density)

Burned Site				Un-Burned Site			
Transect	Length	Shrub #	Shrubs/ ha	Transect	Length	Shrub #	Shrubs/ ha
1	100	20	2000	1	100	30	3000
2	100	45	4500	2	100	45	4500
3	100	30	3000	3	100	50	5000
4	100	47	4700	4	100	10	1000
5	100	30	3000	5	100	37	3700
6	100	42	4200	6	100	37	3700
7	100	X	X	7	100	X	X
8	100	X	X	8	100	X	X
9	100	X	X	9	100	X	X
10	100	X	X	10	100	X	X
11	100	X	X	11	100	X	X
12	100	X	X	12	100	X	X
13	100	X	X	13	100	X	X
14	100	X	X	14	100	X	X
15	100	X	X	15	100	X	X
16	100	X	X	16	100	X	X
Mean <b>3566</b>				Mean <b>3483</b>			
<b>Total</b>		<b>214</b>		<b>Total</b>		<b>209</b>	

What is the problem with this data set?

**1 Hectare = 10,000m<sup>2</sup>**      **(Ticks or Shrubs)/ ha = (# / Length X (10,000))**  
**Mean = (Sum of all transects) / (# of transects)**

Pre-Burn (Shrub Density) 2005											
Burned Site						Un-Burned Site					
Transect	Length	Shrub #	Live	Dead	Shrubs/ ha	Transect	Length	Shrub #	Live	Dead	Shrubs/ ha
1	100	20	18	2	2000	1	100	30	28	2	3000
2	100	45	43	2	4500	2	100	45	41	4	4500
3	100	30	30	0	3000	3	100	50	56	4	5000
4	100	47	46	1	4700	4	100	10	10	0	1000
5	100	30	28	2	3000	5	100	37	37	0	3700
6	100	42	39	3	4200	6	100	37	31	6	3700
7	100	45	41	4	4500	7	100	46	40	6	4600
8	100	30	28	2	3000	8	100	58	54	4	5800
9	100	25	23	2	2500	9	100	35	31	4	3500
10	100	38	35	3	3800	10	100	40	39	1	4000
11	100	28	25	3	2800	11	100	X			X
12	100	X			X	12	100	X			X
13	100	X			X	13	100	X			X
14	100	X			X	14	100	X			X
15	100	X			X	15	100	X			X
16	100	X			X	16	100	X			X
<b>Mean</b>			<b>30.1</b>	<b>2.1</b>	<b>3455</b>	<b>Mean</b>			<b>36.7</b>	<b>3.1</b>	<b>3880</b>
<b>Total</b>		<b>380</b>	<b>356</b>			<b>Total</b>		<b>388</b>	<b>367</b>		
% Live Shrubs =						% Live Shrubs=					

Post-Burn % Mortality (Shrub Density) 2006											
Burned Site						Un-Burned Site					
Transect	Length	Shrub #	Live	Dead	Shrubs/ ha	Transect	Length	Shrub #	Live	Dead	Shrubs/ ha
1	100	20	9	11	2000	1	100	30	28	2	3000
2	100	42	10	32	4200	2	100	45	41	4	4500
3	100	30	15	15	3000	3	100	50	54	6	5000
4	100	47	26	21	4700	4	100	10	10	0	1000
5	100	30	18	12	3000	5	100	37	35	2	3700
6	100	42	39	3	4200	6	100	37	30	7	3700
7	100	45	20	25	4500	7	100	46	41	5	4600
8	100	30	15	15	3000	8	100	58	54	4	5800
9	100	25	23	2	2500	9	100	35	30	5	3500
10	100	38	20	18	3800	10	100	40	32	8	4000
11	100	28	25	3	2800	11	100	X			X
12	100	X			X	12	100	X			X
13	100	X			X	13	100	X			X
14	100	X			X	14	100	X			X
15	100	X			X	15	100	X			X
16	100	X			X	16	100	X			X
<b>Mean</b>			<b>21.5</b>	<b>15.2</b>	<b>3427</b>	<b>Mean</b>			<b>35.5</b>	<b>4.3</b>	<b>3483</b>
<b>Total</b>		<b>377</b>	<b>220</b>			<b>Total</b>		<b>388</b>	<b>355</b>		
% Live Shrubs =						% Live Shrubs =					

**% Live Shrubs = (Total Live/ Total Shrub # ) X 100%**

**Percent Reduction = 1 - (mean 1/ mean 2) X100%**

The data which were made up for this example indicate that shrub density was affected by the fire. The data is powerful because it shows that the treatment and control sites had similar shrub density and % live shrubs before the fire occurred. Because the un-burned control has not changed significantly we can attribute the changes in the burned site to the prescribed fire.

## Example Calculation (Herbaceous Cover)

(Assumes 10 plots/ transect, using a standard frame size)

Burned Site					Un-Burned Site							
Transect	# Plots Averaged	Grass Cover	Forb Cover	Bare Ground	Transect	# Plots Averaged	Grass Cover	Forb Cover	Bare Ground			
1	10	23	50	27	1	10	51	27	23			
2	10	23	51	26	2	10	49	27	23			
3	10	24	50	26	3	10	50	27	24			
4	10	X	X	X	4	10	X	X	X			
5	10	X	X	X	5	10	X	X	X			
6	10	X	X	X	6	10	X	X	X			
7	10	X	X	X	7	10	X	X	X			
8	10	X	X	X	8	10	X	X	X			
9	10	X	X	X	9	10	X	X	X			
10	10	X	X	X	10	10	X	X	X			
11	10	X	X	X	11	10	X	X	X			
12	10	X	X	X	12	10	X	X	X			
13	10	X	X	X	13	10	X	X	X			
14	10	X	X	X	14	10	X	X	X			
15	10	X	X	X	15	10	X	X	X			
16	10	X	X	X	16	10	X	X	X			
<b>Mean</b>				<b>23</b>	<b>50</b>	<b>Mean</b>				<b>50</b>	<b>27</b>	<b>23</b>

Transect #1 (Burn)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1	30	40	30
2	20	50	30
3	30	50	20
4	10	60	30
5	20	50	30
6	30	50	20
7	10	60	30
8	30	40	30
9	20	50	30
10	30	50	20
Mean	23	50	27

Transect #2 (Burn)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1	30	50	20
2	10	60	30
3	20	50	30
4	30	50	20
5	10	60	30
6	30	40	30
7	20	50	30
8	30	50	20
9	20	50	30
10	30	50	20
Mean	23	51	26

Transect #3 (Burn)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1	30	40	30
2	20	50	30
3	30	50	20
4	20	50	30
5	30	50	20
6	20	50	30
7	30	50	20
8	10	60	30
9	20	50	30
10	30	50	20
Mean	24	50	26

Transect #1 (Un-burned)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1	50	30	30
2	60	20	10
3	50	30	20
4	50	30	30
5	60	30	10
6	40	20	30
7	50	30	20
8	60	20	30
9	40	30	20
10	50	30	30
Mean	51	27	23

Transect #2 (Un-burned)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1	40	20	30
2	50	30	20
3	50	30	30
4	50	20	10
5	50	30	20
6	50	30	30
7	50	30	10
8	60	20	30
9	40	30	20
10	50	30	30
Mean	49	27	23

Transect #3 (Un-Burned)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1	40	30	30
2	50	30	20
3	50	20	30
4	50	30	20
5	50	20	30
6	50	30	20
7	50	20	30
8	60	30	10
9	50	30	20
10	50	30	30
Mean	50	27	24



FRWS 5410  
Lab I: Cover

Name(s): \_\_\_\_\_ Date: \_\_\_\_\_ Page    of   

Site Location (GPS): \_\_\_\_\_

Site Comments: \_\_\_\_\_

Method: Quadrat (0.25 m<sup>2</sup> or 0.50 m<sup>2</sup>) Response Variable(s): \_\_\_\_\_

Plot No.	Cover Classes (%)						Cover Class Mid-Pt
	T	0.1-5	6-25	26-50	51-75	76-95	
1			\				15.5
2			\				15.5
3	\						0
4		\					2.5
5	\						0
6	\						0
7			\				15.5
8	\						0
9	\						0
10		\					2.5
11						Total	123.5
12							
13							
14							
15							
16							
17							
18							
19							
20							

The mid-points for the six classes, respectively, are 2.5, 15.5, 38.0, 63.0, 85.5, and 98.0. If a plant occurred across 30 plots a total of 20 times, and was found 9 times in cover class 1, 7 times in cover class 2, 2 times in cover class 3 and 2 times in cover class 4, then the overall average would be  $[(10 \times 0) + (9 \times 2.5) + (7 \times 15.5) + (2 \times 38.0) + (2 \times 63.0)]$  divided by 30, or 11.1%.



# Unit 3

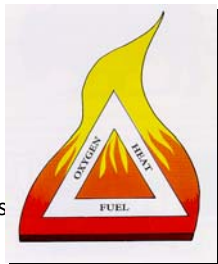
## Fire Behavior



## Fire Behavior

- Fuels
- Weather
- Topography

*Don't worry about the details*



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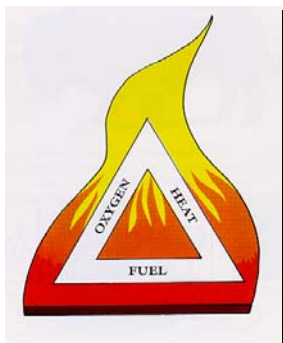
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## Fire Triangle

For a fire to burn all three elements; heat, fuel, and oxygen must be present



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## Heat Transfer

- **Radiation**
  - Transfer of heat by rays of energy (campfire)
- **Convection**
  - Transfer of heat by air (smoke)
- **Conduction**
  - Transfer of heat by touching (stove)



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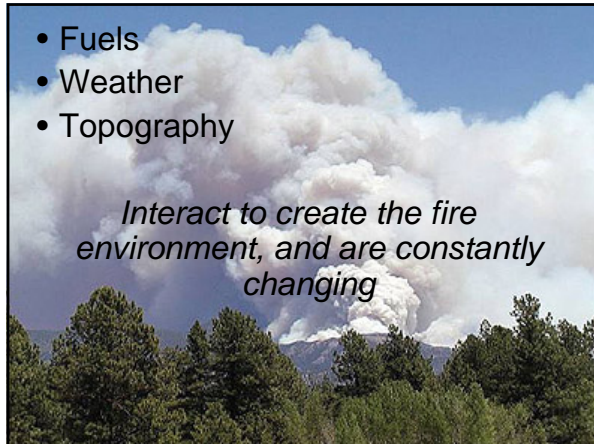
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- Fuels
- Weather
- Topography

*Interact to create the fire environment, and are constantly changing*



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**Fuels**  
Weather  
Topography

- Fuel Type
- Fuel Moisture
- Size and Shape (light fuels vs. heavy fuels)
- Fuel Loading
- Horizontal Continuity (uniform and patchy)
- Vertical Arrangement (ground, surface, aerial)

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**Fuel Types**

- Grass
- Shrub
- Leaf Litter
- Slash



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### Fuel Moisture

$$FM = \frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Dry Weight}} \times 100\%$$

The amount of water in a fuel, effects how well it will burn

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### Plant Development

FIGURE 3 -- LIVE FUEL (FOLIAGE) MOISTURE CONTENT

MOISTURE CONTENT (Percent)	STAGE OF VEGETATIVE DEVELOPMENT
300	Fresh foliage, annuals developing, early in the growing cycle.
200	Maturing foliage, annuals developing with full turgor.
150	Maturing foliage midway in development cycle.
120	Foliage nearing maturity, new growth nearly complete.
90	Mature foliage, new growth complete and comparable to older perennial foliage.
60	Entering dormancy, coloration starting, some leaves may have dropped from stems.

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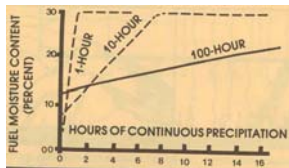
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### Size of Fuels

- 1 hour fuels-** grasses and small twigs < ¼ inch diameter
- 10 hour fuels-** twigs ¼ to 1 inch in diameter
- 100 hour fuels-** stems 1 to 3 inches in diameter
- 1000 hour fuels-** stems and logs > 3 inches




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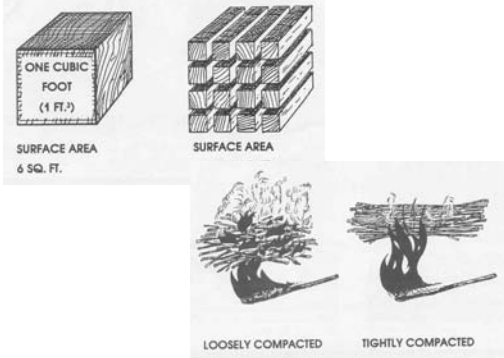
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### Size, Shape, and compactness



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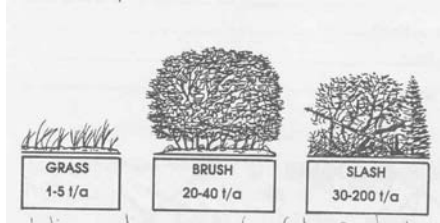
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### Fuel Loading



The quantity of fuels in an area (tons/acre).



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### Horizontal Continuity

#### Uniform Fuels

#### Patchy Fuels



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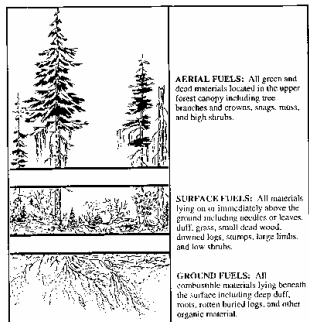
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## Vertical Arrangement of Fuels



**Ladder fuels-** connect the ground fuel to the canopy fuel, can create extremely hot fire

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## Fuels Weather Topography



- **Temperature -Heat**
- **Wind- Oxygen**
  - Increases supply of oxygen.
  - Drives convective heat into adjacent fuels.
  - Influences direction of fire spread and fire spotting.
  - Dries fuels if the air is dry.
  - Raises fuel moisture if the air contains moisture.
- **Relative Humidity (RH) - fuel**
  - As RH increases, fuel moisture increases.
- **Precipitation- fuel**
  - Increases fuel moisture
- **Atmospheric Stability**

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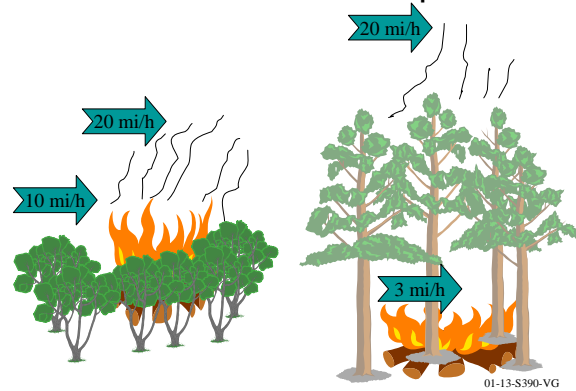
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## Fuel effects on wind speed




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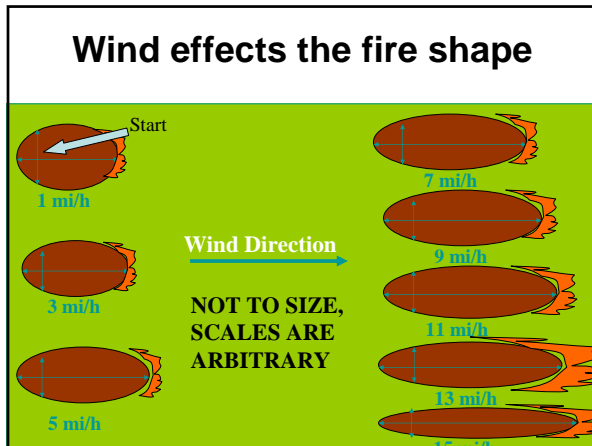
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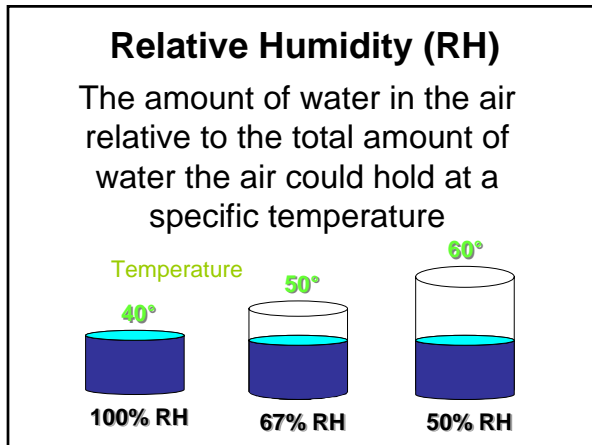
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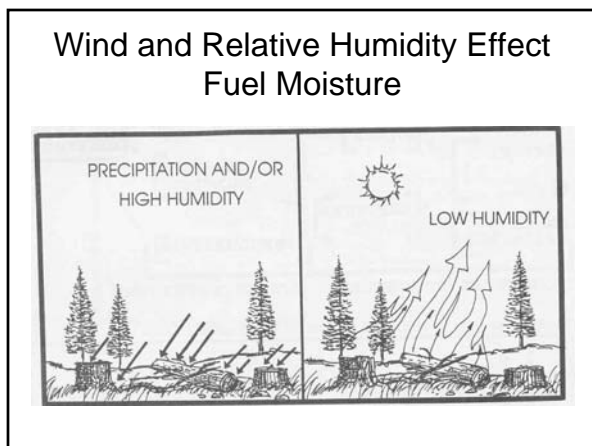
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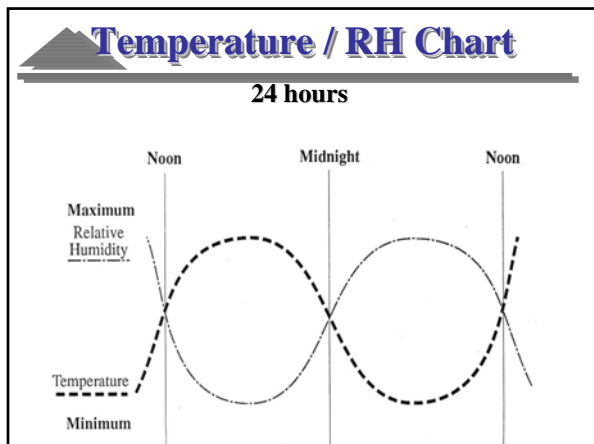
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- Fuels**  
**Weather**  
**Topography**
- **Aspect?** -north, east, south, west
  - **Slope**
    - Steepness
    - Position -Top, middle, or bottom of slope
  - **Elevation**
    - Relates to drying of fuels, precipitation, length of fire season, etc.
  - **Shape of the land**
    - Narrow canyons, ridges, flat

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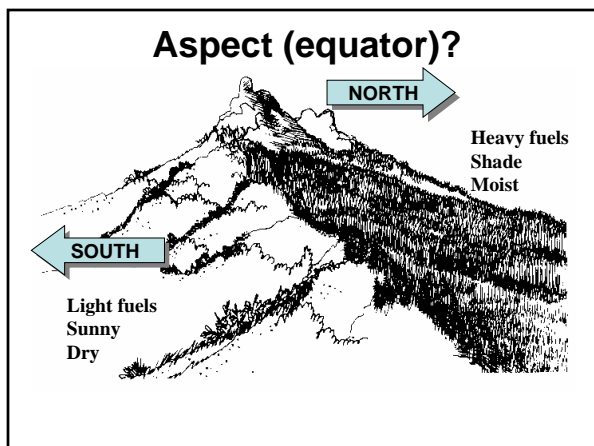
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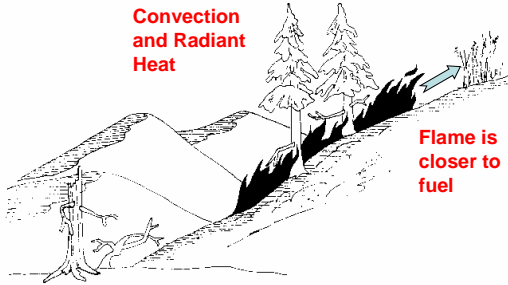
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### Steep Slopes Cause Rapid Fire Spread



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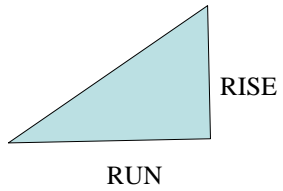
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### PERCENT SLOPE

$$\% \text{ SLOPE} = \frac{\text{RISE IN METERS}}{\text{RUN IN METERS}} \times 100 \%$$



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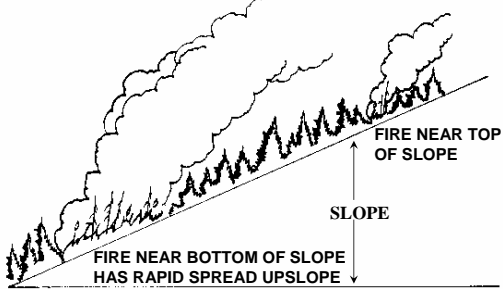
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### Slope Position



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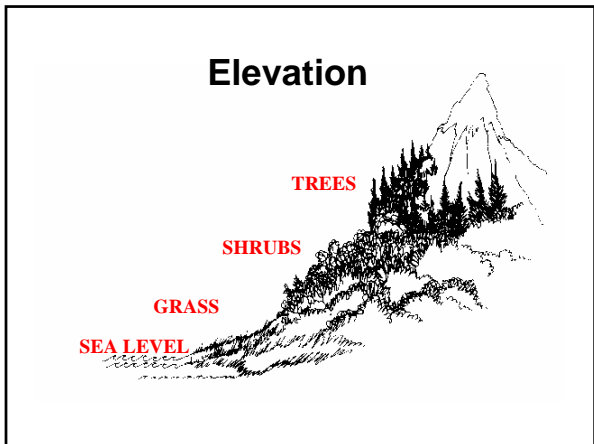
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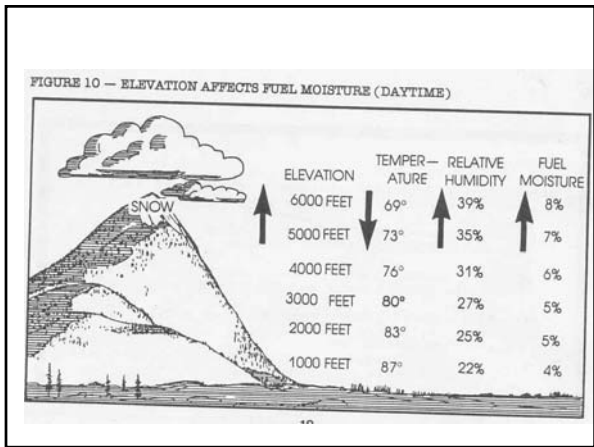
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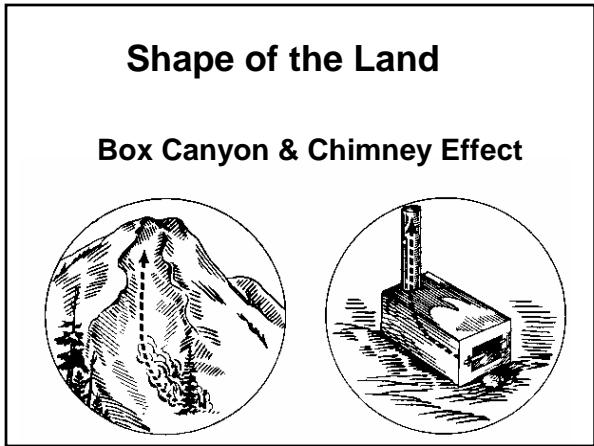
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**Shape of the Land**

**Radiant Heat Across Narrow Canyon**



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**Shape of the Land**

**Spotting Across Narrow Canyon**



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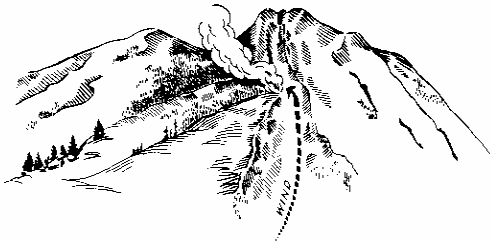
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**Shape of the Land**

**Lateral Ridge to Canyon**



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### Shape of the Land

#### Mountains Cause Channeling of Wind



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### Summary

- Grass and Shrubs Burn differently!
- Pay Attention to the Weather!
  - Wind Speed and Direction
  - Temperature
  - Humidity
  - Know the Daily and Seasonal Patterns
- Be Familiar with the Topography!
- Start Small Test Fires First!

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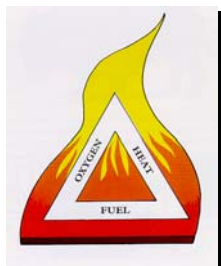
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### Fire Behavior Questions?

- Fuels
- Weather
- Topography



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**Fire Weather Monitor**

- Watches and records the fire weather
- Gives periodic reports every 30 min.
- Alerts Crew of dangerous changes in weather



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**Relative Humidity**

The amount of moisture in the air relative to the maximum amount it could hold when saturated

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### DRY BULB TEMPERATURE

The temperature of the air

### Wet Bulb Temperature

Lowest temperature to which air can be cooled by evaporation

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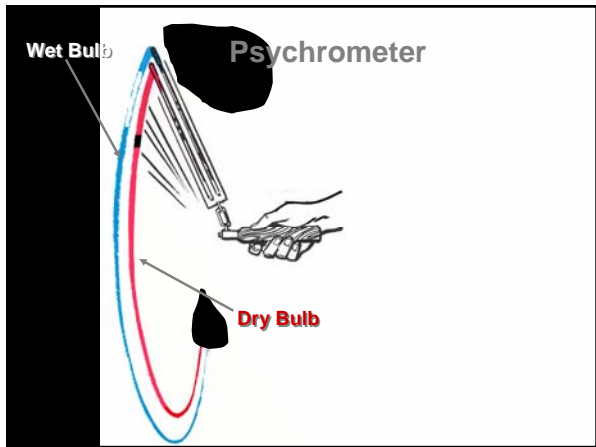
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### TEMPERATURE/RELATIVE HUMIDITY TABLE

A detailed psychrometric chart showing the relationship between dry bulb temperature and relative humidity. The chart includes a grid for dry bulb temperatures (horizontal axis) and wet bulb temperatures (vertical axis). The chart is titled 'TEMPERATURE/RELATIVE HUMIDITY TABLE' and 'WET BULB TEMPERATURES'.

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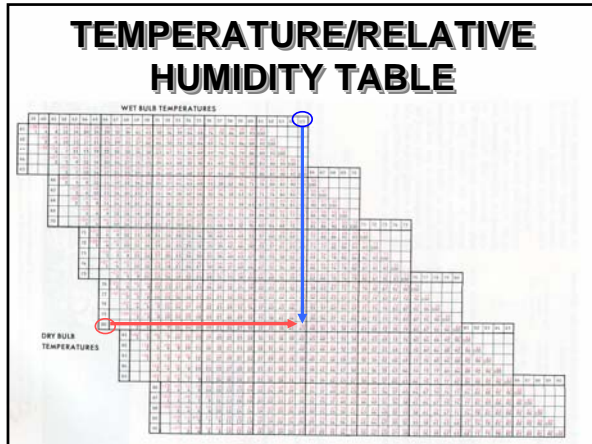
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### RELATIVE HUMIDITY RULE OF THUMB:

Each 20° F increase in air temperature  
decreases humidity by about half

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### Fire Weather Patterns

Local Weather Patterns

- Cold fronts
- Thunderstorms
- Fohen Whinds
- Atmospheric stability

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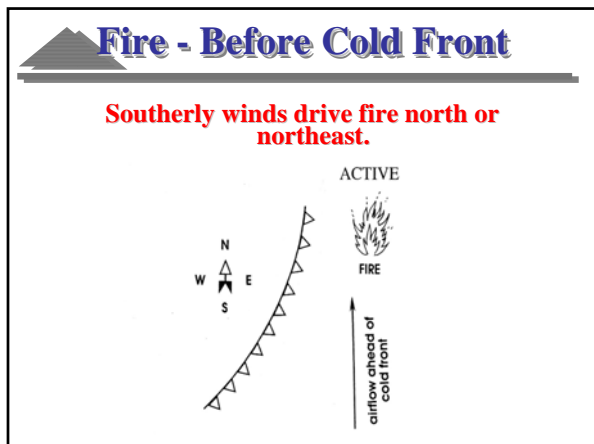
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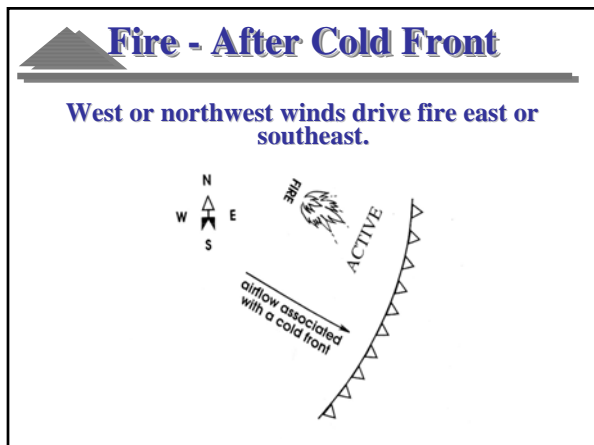
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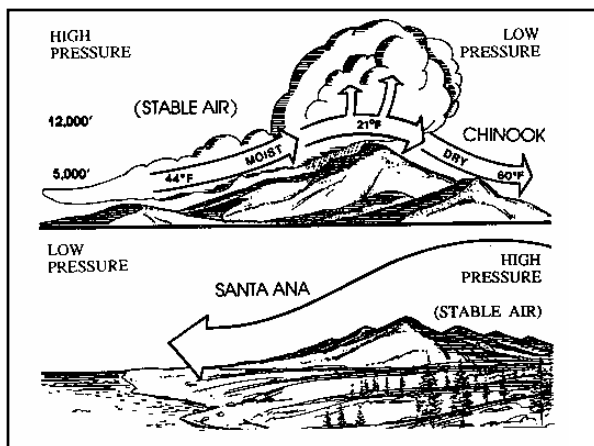
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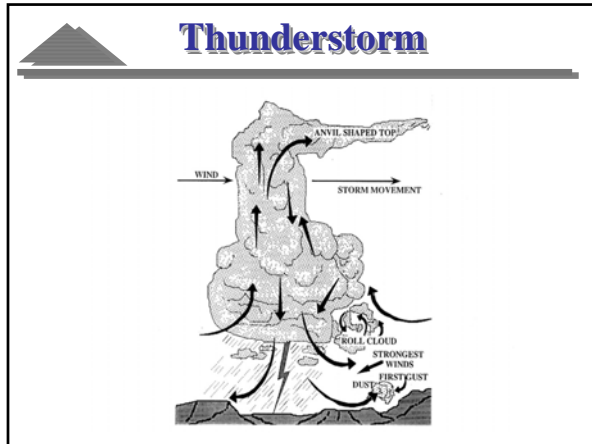
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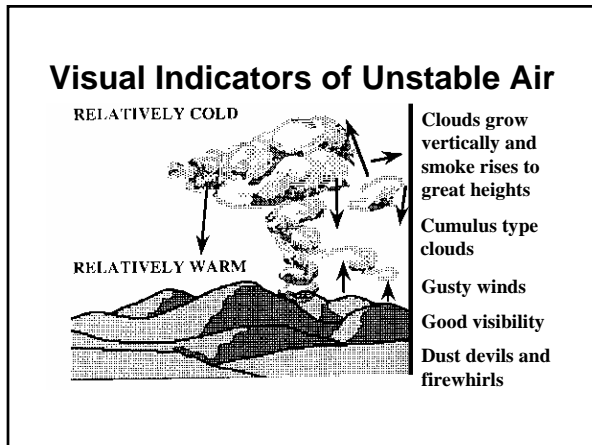
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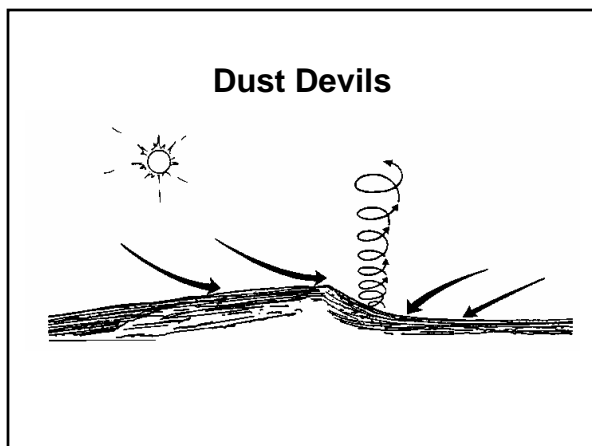
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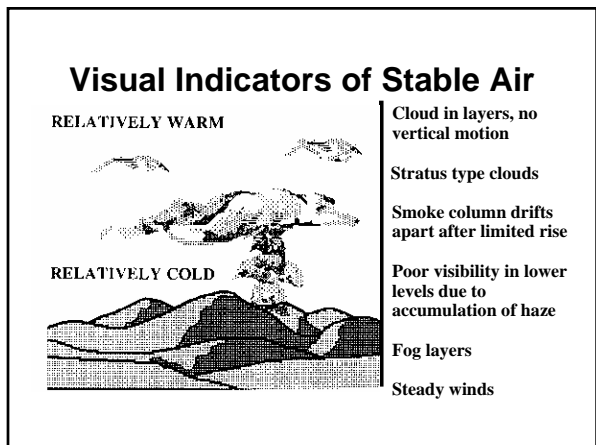
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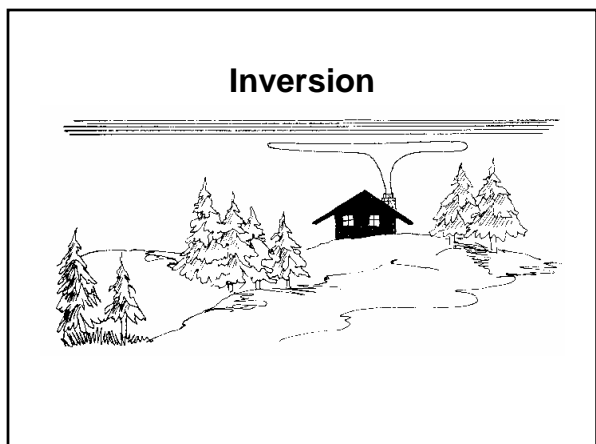
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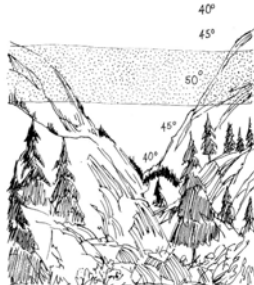
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### Thermal Belt

Region of warmer air on middle third of slope.



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### Conclusion on Weather Patterns

- Common Weather patterns will occur in different regions of the country.
- Be familiar with local weather when planning the prescribed fire.
- Pay attention to potential weather changes while you are burning.

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### Fire Behavior Monitoring

*The way fire behaves determines it's effects on vegetation and insects*

- Fire behavior description
- Fire behavior measurement

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### Fire Behavior description

- Fire spread characteristics
  - “the fire backed in the surface fuels under the oaks without consuming the crowns”
  - “the fire torched individual trees while consuming all of the shrubs”

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### Fire Behavior definitions

- Ground fire –
- Surface fire –
- Crown fire –
- Torching –
- Spotting -

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**Ground fire:**

- Flameless
- Burns slowly through organic layer on soil surface
- Can be more destructive than it looks!

(root death)

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**Surface fire:**  
Burns litter, dead wood, understory plants  
Burns rapidly

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**Crown fire:**  
- tree crowns burned  
- can leave forest floor untouched,  
If moving very fast

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**Fire Monitoring**

- Measuring Fire Behavior
  - Measures of fire intensity
    - Rate of Spread
    - Flame Length



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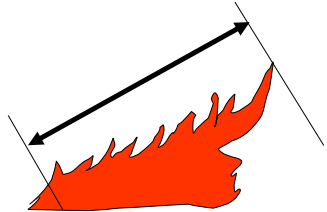
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### FLAME LENGTH (meters)



- Estimate using an object of reference
- May change through out the burn area

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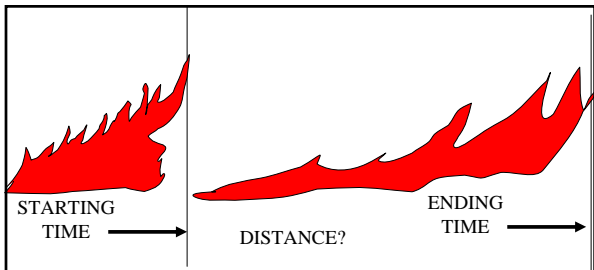
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### RATE OF SPREAD

DISTANCE/TIME  
(Meters/ Second)

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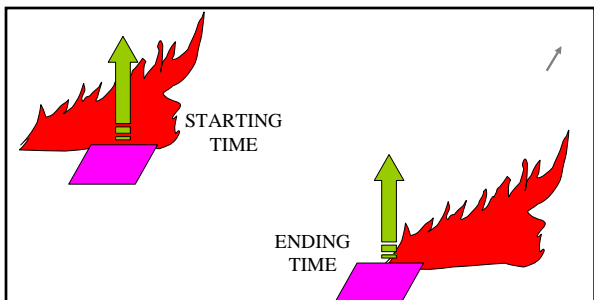
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### HEAT PER UNIT AREA

Btu/sq ft

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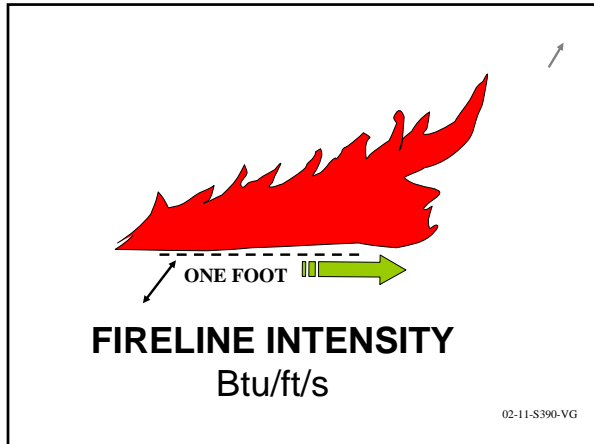
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### Tools to take

- Data sheets
- Maps
- Pencil
- Compass and GPS
- Camera
- Belt Weather Kit
- Radio



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Extreme Fire Behavior

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Indicators of Problem and Extreme Fire Behavior

**Fuel Indicators**

- Unusually dry fuels.
- Large amount of light fuel (shrubs, grass, needles).
- Fuels exposed to direct sunlight.
- Fuels dried by prolonged drought.
- Ladder fuels that allow a surface fire to move into the crowns of shrubs or trees.
- Crown foliage dried by surface fire.
- Concentration of snags.

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Indicators of Problem and Extreme Fire Behavior

**Topography Indicators**

- Steep slopes.
- Chutes, saddles, and box canyons which provide conditions for "chimney effect."
- Narrow canyons may increase fire spread by radiant heat and spotting.

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Indicators of Problem and Extreme Fire Behavior

**Weather Indicators**

- Strong Wind.
- Sudden changes in wind direction and speed.
- High, fast-moving clouds may indicate unusual surface winds.
- Unexpected calm may indicate wind shift.
- Thunderstorms above or close to the fire.
- High temperatures and low relative humidity.
- Dust devils and whirlwinds developing.
- Bent smoke column.

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Indicators of Problem and Extreme Fire Behavior

**Fire Behavior Indicators**

- Keep an eye on the smoke column. Indicates direction of fire spread, location of spot fires, and changes in fire intensity.
- Smoldering fires increase in intensity.
- Fire begins to torch small groups of trees or shrubs.
- Frequent spot fires occurring.
- Firewhirls beginning to develop inside the main fire.
- Crown fires.

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# Unit 4

## Fire Planning and Implementation





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Prescriptions and the fire planning process

Objectives

1. Identify the key elements that must be addressed in a prescribed burn plan.
2. Describe the process in developing a prescribed burn plan.
3. Write clear and measurable objectives for a specific burn.

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**Prescribed Fire:**

A fire lit under specified fuel and weather conditions that result in a particular fire behavior (a prescription) to achieve resource and management objectives in a particular area.

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### Burn Prescription

A written statement defining the range of temperature, humidity, wind speed and, fuel moisture, etc. under which a given area will be allowed to burn to obtain given objectives.



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### Burn Plan

A burn plan includes a fire prescription as well as other tasks that must be accomplished before, during and after a burn to safely meet burn objectives.

- Fire breaks/ site preparation
- Contact neighbors
- Contingency plan



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### Successful Burn Planning is Based on:

- Previous experience from similar treatments on similar sites
- Communication with interested/affected communities and government

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### DEVELOPING A PRESCRIBED BURN PLAN

A prescribed burn plan is developed to help achieve a burn that:

- Is conducted safely.
- Remains within prescription parameters.
- Attains specified land, resource management, or conservation goals and treatment objectives.
- Complies with legal planning requirements and responsibilities.

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### Planning Based on:

- Goals and treatment objectives for the site.
- Physical and biological characteristics of the site.
- Known (*or suspected*) relationships among
  - 1) pre-burn environmental factors
  - 2) expected fire behavior
  - 3) probable fire effects.

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### ELEMENTS OF A PRESCRIBED BURN PLAN

- objectives
- Ranges for prescription parameters
- Compliance with laws and agency policies
- Operational and contingency plans
- Monitoring and documentation process
- Review and approval process

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# PRESCRIBED FIRE PLAN

**State:**  
**Preserve/Site:**  
**Burn Unit:**  
**Permit #:** \_\_\_\_\_

**Fire Planner(s):**

*Name:* \_\_\_\_\_ *Signature* \_\_\_\_\_ *Date* \_\_\_\_\_  
*Title:* \_\_\_\_\_

*Name:* \_\_\_\_\_ *Signature* \_\_\_\_\_ *Date* \_\_\_\_\_  
*Title:* \_\_\_\_\_

**Burn Boss:**

*Name:* \_\_\_\_\_ *Signature* \_\_\_\_\_ *Date* \_\_\_\_\_  
*Title:* \_\_\_\_\_

**Fire Manager:**

*Name:* \_\_\_\_\_ *Signature* \_\_\_\_\_ *Date* \_\_\_\_\_  
*Title:* \_\_\_\_\_

**Attachments:**

Preserve/site burn units map:	Yes / No
Burn Unit fuels/crew map:	Yes / No
Aerial photograph:	Yes / No
Contingency map(s):	Yes / No
Vicinity Map:	Yes / No
Evacuation/Hospital Map:	Yes / No
Burn Permit application/approval:	Yes / No

**1. GEOGRAPHIC INFORMATION:**

County/State:  
 Ownership:  
 T/R/Sec.:  
 Lat/Long or UTM:  
 Unit Acres:  
 Fireline Perimeter:

**2. SOURCES OF EMERGENCY ASSISTANCE** (location & phone #):

Fire:  
 Law Enforcement:  
 Medical:  
 Attorney:  
 Nearest land-line telephone to unit:

**3. PERMITS:**

Burn Permit/Notification Required?                      Yes / No  
 Source(s):

**4. REQUIRED NOTIFICATIONS:** List all agencies and neighbors

Name	Date (before, day of, after burn)	Method (email, mail, phone, etc)	Contact Information

**5. UNIT DESCRIPTION:**

Vegetation Types	Fuel Models	% of Unit Area	% Slope	Aspect

**Burn Unit Description** (include description of fuels outside of burn unit, shape of unit, topographic features, etc.):

**Picture of dominant Unit Fuels**

**6. PRESCRIBED BURN JUSTIFICATION:** Type of Burn (ecological management, hazard reduction, training, research):

**Burn Unit Management Goals:**

**Specific Burn Objectives:**

## 7. FUEL AND WEATHER PRESCRIPTION (give acceptable ranges)

<b>Fuel Parameters:</b>	<b>MIN</b>	<b>PREFERRED</b>	<b>MAX</b>
1-Hour Fuel Moisture (%)			
10-Hour Fuel Moisture (%)			
100-Hour Fuel Moisture (%)			
Live Fuel Moisture (%)			
Other (e.g. KBDI, Live/dead ratio):			
<b>Weather Parameters:</b>			
Air Temperature (°C)			
Relative Humidity (%)			
Days Since Rain			
20 ft wind speed (kph)			
Wind Direction(s)			
Midflame Windspeed (kph)			
Atmospheric Mixing Height (m)			

List any combinations of parameters that you will exclude from your burn window (e.g. high windspeeds with low 1-hour fuel moisture).

Other Comments:

8. **PRESCRIBED FIRE BEHAVIOR:** (Describe *desired* fire behavior. How will you manipulate fire behavior to meet management and control objectives?):
9. **PREDICTED BEHAVIOR FOR FREE BURNING FIRE** (Outputs from BEHAVE PLUS: use inputs from #7; include predictions for fuels surrounding burn unit), include a chart for each fuel model used. **Use this information as a guide to the potential range of behavior from a free-burning fire, and for contingency planning.**

FUEL MODEL #	ACCEPTABLE FIRE BEHAVIOR RANGE		
	MIN	PREFERRED	MAX
Rate of spread (m/hr)			
Headfire flame length (m)			
Backfire flame length (m)			
Scorch height (m)			
Spotting distance (km)			
Probability of ignition (%)			

FUEL MODEL #	ACCEPTABLE FIRE BEHAVIOR RANGE		
	MIN	PREFERRED	MAX
Rate of spread (m/hr)			
Headfire flame length (m)			
Backfire flame length (m)			
Scorch height (m)			
Spotting distance (km)			
Probability of ignition (%)			

## 10. CREW ORGANIZATION

Qualified Burn Boss(s):

Crew Number: to

Organizational chart:

## 11. EQUIPMENT

Equipment Item	Quantity	Source
*Radios (minimum of 3)		
*Weather Kit		
*First Aid kit		
* Required Items		

**12. MANAGING THE BURN** (Describe each of the following):**Burn Duration:**

**Will this burn be implemented or continue after dark?**

**Will the burn exceed 1 burning period?**

**Firebreak preparations:****Safety zones and Escape Routes:****Unusual hazards to crew:****Ignition Plan:****Holding Plan (include known critical holding concerns):****Type and location of water source:****Fire sensitive areas:****Fire behavior and weather monitoring:****Mop-up:****Public Access/Conflicts with Public use:****Post Fire Rehabilitation plan:**

### 13. CONTINGENCY PLAN

Escape response procedures:

Who declares an escaped fire?

Who will direct the suppression efforts until response authority arrives?

Location, description, and availability of nearest emergency resources:

Description	Contact Point Person	Contact Method (phone, radio frequency)	Availability	Response Time (from time of call to arrival on scene)

Secondary control lines:

North

South

East

West

Back-up water sources:

**14. SAFETY PLAN** (route to Hospital, location of first aid kit, sources of emergency

### 17. LEGAL CONSIDERATIONS

Describe the ownership/management responsibility of this site:

Releases/waivers required? Yes / No

Releases/waivers attached? Yes / No



## PRE-BURN CHECKLIST AND CREW BRIEFING

**Preserve:**

**Fire Unit:**

**Date:**

### A. PRIOR TO CREW BRIEFING

- Fire Unit is as described in plan.
- Required firebreaks complete.
- Permits obtained. Give permit #'s:
- Official and neighbor notifications complete.
- Required equipment is on-site and functioning.
- Planned ignition and containment methods are appropriate.
- List of emergency phone numbers are in each vehicle.
- Planned contingencies and mop-up are appropriate.

### B CREW BRIEFING

- Each crew member has a burn unit map.
- Fire Unit size and boundaries discussed.
- Fire Unit hazards discussed.
- Purpose of burn.
- Anticipated fire and smoke behavior.
- Review of equipment and troubleshooting.
- Check crew qualifications.
- Review organization of crew and assignments.
- Review methods of ignition, holding, mop-up, communications.
- Review contact with the public; traffic concerns.
- Location of vehicles, keys, and nearest phone.
- Location of back-up equipment, supplies, and water.
- Review all contingencies including escape routes.
- Review mop-up procedures.
- Answer questions from crew.
- Give crew members the opportunity to decline participation.

### C. PRIOR TO IGNITION

- Weather and fuel conditions are within prescriptions.
- Weather forecast, obtained within two hours of ignition, says prescribed weather will hold for two hours past expected duration of burn.
- Crew members have required protective clothing.
- Crew members have matches.
- Conduct test burn.

### D. BEFORE LEAVING BURN UNIT

- Mop-up completed as described in burn plan.
- Next morning inspection arranged.
- Notifications of completed burn (if required).

### E. NOTE ANY MODIFICATIONS TO Burn Plans

**Burn Boss:**

**Date:**



## NWCG PRESCRIBED FIRE GO/NO-GO CHECKLIST

Yes	No	Questions
		Are ALL fire prescription elements met?
		Are ALL smoke management specifications met?
		Has ALL required current and projected fire weather forecast been obtained and are they it favorable?
		Are ALL planned operations personnel and equipment on-site, available, and operational?
		Has the availability of ALL contingency resources been checked, and are they available?
		Have ALL personnel been briefed on the project objectives, their assignment, safety hazards, escape routes, and safety zones?
		Have all the pre-burn considerations identified in the prescribed fire plan been completed or addressed?
		Have ALL the required notifications been made?
		Are ALL permits and clearances obtained?
		In your opinion, can the burn be carried out according to the prescribed fire plan and will it meet the planned objective?

If all the questions were answered "YES" proceed with a test fire. Document the current conditions, location, and results

## Implementing a Fire

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- ### Questions to ask the day of the burn
- Fuels the same?
  - Topography accurately indicated on map?
  - Firebreaks completed? Secondary breaks?
    - Will they contain the fire, are they adequate?
  - Why is the wind blowing so hard?
  - New hazards (people, cattle, etc)

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### Weather and fuel moisture assessment

- Take the weather on-site, and pay attention to trends



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### Trigger point (go/no go decision)



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### Pre-burn Checklist and Crew Briefing

- Crew
- Equipment
- Pre-burn prep tasks
- Distribute maps for their crew members



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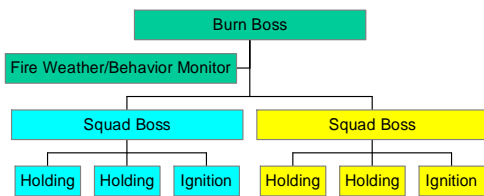
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### Crew Organization



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## Test Fire

- Why a test fire?
  - Verify anticipated fire behavior
  - Verify that you can meet your objectives
- Document your observations




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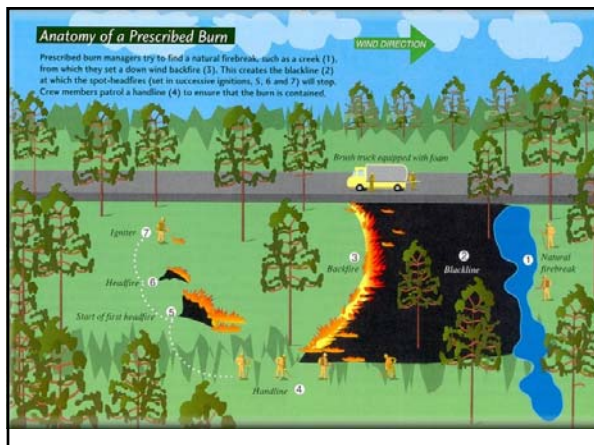
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## Post fire Review– Crew Duties

How did it go?

- Was safety compromised?
- Take suggestions for improvement from crew (allow everyone to speak).
- Make assignments/ arrangements for next-day visit and mop- up if needed.

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After Fire Review with crew

- What did we set out to do?
- What actually happened?
- Why did it happen?
- What are we going to do next time?

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Post-fire evaluation

- Make notes and recommendations for next fire
- Monitor to see if objectives have been achieved
- File burn plan with weather forecast, actual conditions, observations, notes, and recommended changes

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### Ignitions in Perspective

- Fire Regimes
- Safety
- Managing the burn
- Fire intensity and severity
- **FIRING TECHNIQUES & MANAGING FOR FIRE EFFECTS**

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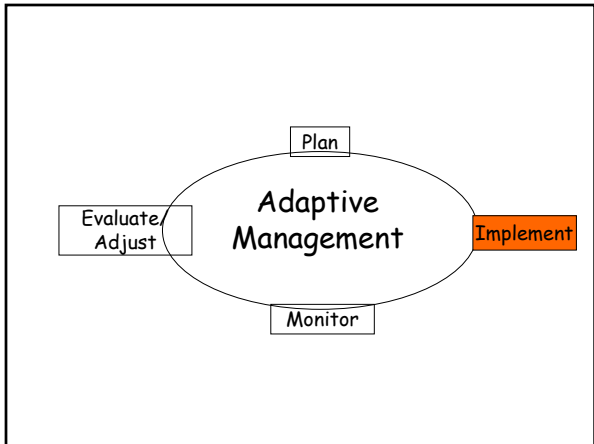
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### A. Ignition Techniques

- Strip-head fire
- Flank fire
- Spot fire
- Ring fire
- Backfire



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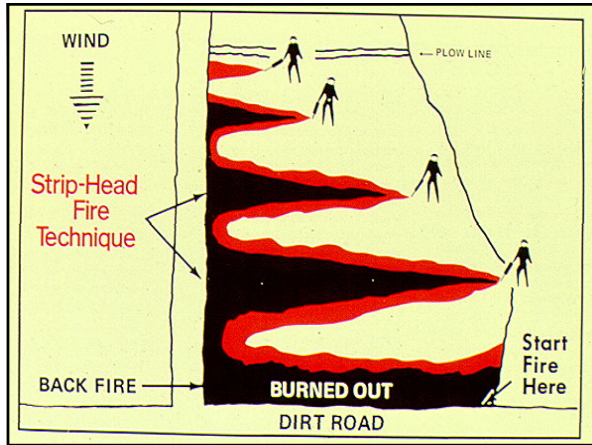
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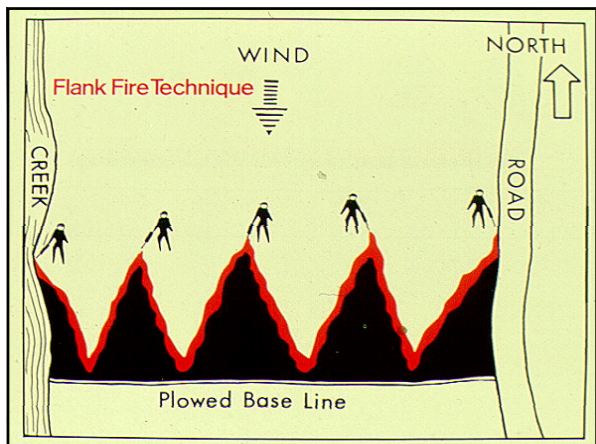
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Flank Fire

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Flanking across a slope

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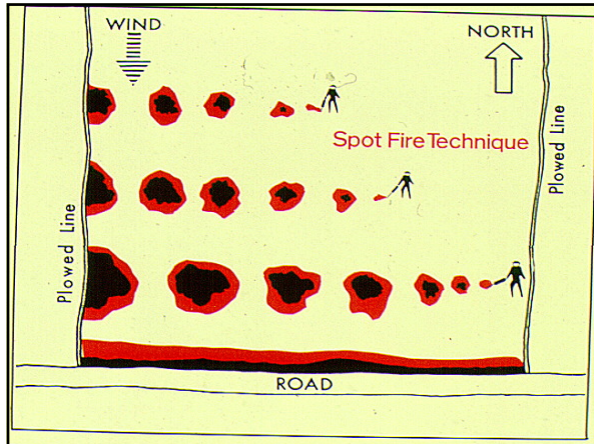
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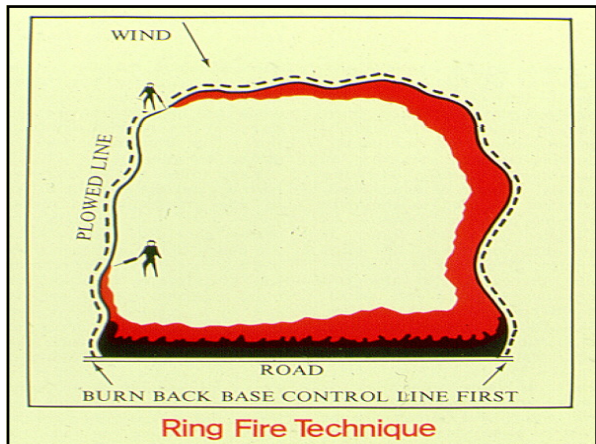
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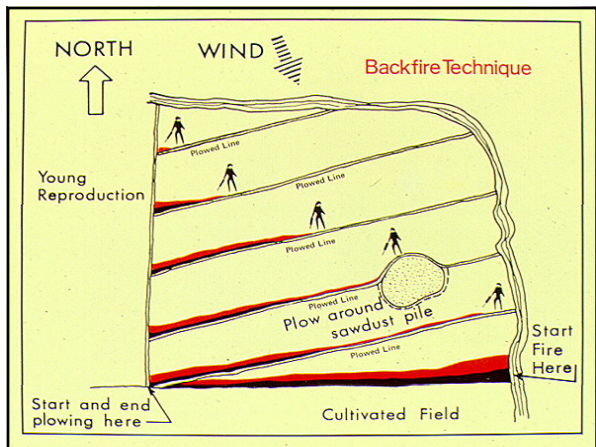
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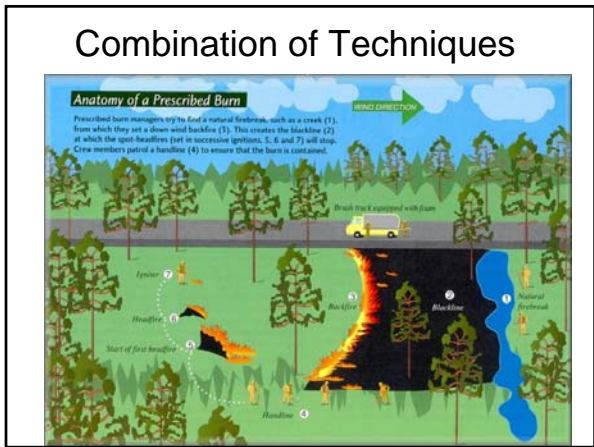
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### DRIP TORCH FUEL MIX RATIO

GASOLINE	DIESEL	VOLATILITY
1 gallon/ liter	4 gallons/ liters	low
1 gallon/ liter	3 gallons/ liters	moderate
2 gallons/ liters	2 gallons/ liters	high

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### Fuel Continuity



How effective is this ignition?

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### Burn objective?



Type of fire?

Fire effects?

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### Burn objectives?



Open Ponderosa pine



Ponderosa pine with decades of fire suppression

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Discussion: Managing for effects:  
arid grasslands



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Under the right conditions, light  
fuels can produce high mortality  
and moderate severity



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In summary

- Ignition technique should be driven by the management and burn objective(s) and take weather, fuel condition (moisture) and fuel structure into account.
- What other considerations?

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### Seasonal considerations



Season matters as well as ignition pattern!



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### Safety (fire break) considerations



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### Landscape considerations



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### Wildlife considerations



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### Human value considerations



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### Managing Ignitions for Fire Effects

It is complex and needs to include:

- Burn objectives
- Anticipated impacts
- Surroundings
- Safety
- Weather
- Fuel conditions

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## Firefighter Training

*Safety is defined as freedom from exposure to danger.*



*Photo by: Steve Karkanen*

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## Safety Rules

- LCES - Lookouts, Communications, Escape Routes and Safety Zones
- The 18 Situations that Shout Watch Out
- The Ten Standard Fire Orders




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## Fire Suppression Hazards

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| <ul style="list-style-type: none"> <li>• <b>Environmental</b> <ul style="list-style-type: none"> <li>- Lightning</li> <li>- Snags</li> <li>- Rolling rocks</li> <li>- Fire entrapment</li> <li>- Heat stress</li> <li>- Darkness</li> <li>- Carbon monoxide</li> <li>- Dust</li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>• <b>Biological</b> <ul style="list-style-type: none"> <li>- Snakes</li> <li>- Insects</li> <li>- Animals</li> <li>- Plants</li> <li>- Microorganisms</li> <li>- <b>Alert me of these things!!!!</b></li> </ul> </li> </ul> |
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### Human Related Hazards

- Attitude (poor morale, fear, machismo etc.)
- Physical condition
- Experience level
- Training level
- Fatigue
- Critical stress
- Language Differences

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### Personal Equipment

- Eye protection
- Gloves
- Leather boots
- Socks
- Drinking water
- Hand Tool
- Lighter/ matches



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# Safety

## LCES

Lookouts

Communications

Escape Routes

Safety Zones

## STANDARD FIREFIGHTING ORDERS

1. Keep informed on fire weather conditions and forecasts.
2. Know what your fire is doing at all times.
3. Base all actions on current and expected behavior of the fire.
4. Identify escape routes and safety zones, and make them known.
5. Post lookouts when there is possible danger.
6. Be alert. Keep calm. Think clearly. Act decisively.
7. Maintain prompt communications with your forces, your supervisor and adjoining forces.
8. Give clear instructions and insure they are understood.
9. Maintain control of your forces at all times.
10. Fight fire aggressively, having provided for safety first.

## WATCH OUT SITUATIONS

1. Fire not scouted and sized up.
2. In country not seen in daylight.
3. Safety zones and escape routes not identified.
4. Unfamiliar with weather and local factors influencing fire behavior.
5. Uninformed on strategy, tactics, and hazards.
6. Instructions and assignments not clear.
7. No communication link with crew members or supervisor.
8. Constructing line without safe anchor point.
9. Building fireline downhill with fire below.
10. Attempting frontal assault on fire.
11. Unburned fuel between you and fire.
12. Cannot see main fire; not in contact with someone who can.
13. On a hillside where rolling material can ignite fuel below.
14. Weather becoming hotter and drier.
15. Wind increases and/or changes direction.
16. Getting frequent spot fires across line.
17. Terrain and fuels make escape to safety zones difficult.
18. Taking a nap near fireline.

### Fire Suppression



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### Suppression Parts of a Fire

- Head
- Finger
- Flank
- Rear
- Perimeter
- Island
- Anchor point
- Spot fires
- Direct attack
- Indirect attack
- Parallel attack

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### Black-line Concept

- The only safe line is a black line (burnt).
- Fuels between the main fire and the control line are burned out, or allowed to burn to the control line.
- This fuels and heat must remain inside the control line.

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### Suppression Type of Fire Control Line

- Natural control line
  - Cold fire edge
  - Fuel break
    - Streams, lakes, ponds, rock slides and areas of sparse fuels
  - Previously constructed barriers
    - Roads, canals, etc.

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### Methods for Breaking the Fire Triangle



- **Heat** - Cool the fire by applying water, dirt, retardant or a combination
- **Fuel** - Separate the fuel to prevent combustion or remove fuel during fire line construction
- **Oxygen** - Suffocate the fire with dirt or water to rob the fire of oxygen

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### Suppression Fire Line Construction Standards

- Fuel type
- Fuel moisture
- Continuity and arrangement
- Temperatures
- Increases in wind

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### Suppression

#### Threats to Existing Control Lines

- **Spotting**- fire brands moving through the air across fire lines.
- **Rolling debris** - burning materials break free and roll down hill
- **Creeping** - fire burning under the soil
- **Radiant heat** - preheating materials across the control line.

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### Suppression

#### Mop-up

- **Mop-up** – Making sure the fire has stopped burning at the end of the prescribed fire.
- Patrol along control lines to check for spot fires and heat to prevent escaping. Patrol both sides of the control line.

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### Suppression

#### Methods of Mop-up

- Dry mop-up
  - Scraping
  - Digging
  - Stirring
  - Mixing
  - Separating
  - Turning logs

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**Suppression**  
- Mop-up

Sight

- Smoke - Look up as well as down. A treetop may be on fire
- Heat waves
- Steam
- White ash - White ash indicates heat and burning, the ash may be covering hot embers
- Stump holes
- Gnats - Gnats often hover over hot spots
- Select an advantageous spot to rest to observe for signs of hot spots
- Look facing into the sun in shaded areas to see small smokes

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**Suppression**  
- Mop-up

- **Touch**
  - Do not wear gloves
  - At first, feel about 1 inch away using the back or the hand, then carefully with direct contact
- **Smell**
  - Smoke
  - Burning materials and gases that these materials give off
- **Hearing** - listen for the:
  - Crack and pop of burning materials
  - Hiss when water touches hot materials

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**Suppression**  
- Mop-up

- **Break -up and disperse**
  - Remove all **unburned fuels** and throw outside fire control lines
  - Remove all **burning fuels** and throw inside the control line
  - Extinguish any burning fuels

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# Annex A

## Readings



# Rangeland Management and Ecology in East Africa

edited by DJ PRATT and MD GWYNNE

*from contributions by*

J R BLACKIE, A V BOGDAN, R M BREDON, L H BROWN, V L BUNDERSON,  
G E CLASSEN, M FLETCHER, P E GLOVER, P J GREENWAY, M D GWYNNE,  
G W IVENS, JOAN KENWORTHY, H F LAMPREY, R W E LEWIS, Z NAVEH,  
W J A PAYNE, J R PEBERDY, LORD PORTSMOUTH, D J PRATT, J PROCTER,  
RUTH SIMPSON, D R M STEWART, D D THORNTON, J VAN RENSBURG  
*and* L D VESEY FITZGERALD

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**HODDER AND STOUGHTON**

LONDON SYDNEY AUCKLAND TORONTO

factors leading to the original encroachment continue to operate. If, for example, the original problem resulted from overgrazing, then reinvasion is inevitable if overgrazing continues. A dense, competitive grass cover is quite essential, and must be provided by reseeding if necessary (Pratt 1966a, Brzostowski and Owen 1964). Even with a good grass cover and skilful management, additional treatment may be needed from time to time, either in the form of a burning rotation or by occasional cutting or spraying.

### Fire

Fire is one of the most controversial subjects in range management. Even at the scientific level, there is an apparent paradox in the fact that fire can control bush-encroachment but that most woody species are relatively tolerant of fire, having evolved under the influence of regular burning. In this case, as at other levels of conflict, much of the difficulty stems from the over-generalizations discussed in Chapter 13. In agronomic research, responses to fertilizer would never be presented without reference to the exact dosage and the number of applications, yet it still seems acceptable to refer to fire and fire susceptibility in the loosest of terms. In fact, there is a world of difference between a fire of 300°C and one that reaches 700°C; between one fire and a sequence of planned fires, or between annual and biennial burning (Thomas and Pratt 1967).

The primary advantage of burning as a method of bush-control is the low capital outlay involved. Although the cost is related nominally to the value of the grass burnt, burning is most often carried out when there is grass in excess of requirements. Of greater significance is the loss of grazing after burning, during the period of recovery. With good rains, grazing may be possible in less than three months, but prolonged drought or premature grazing can impair the productivity of the grass for several seasons (Pratt 1967). Other costs are restricted largely to the construction and maintenance of firebreaks, and to the labour needed to ensure that fires do not get out of control.

The effects of burning have been studied in Kenya by Bogdan (1954), Edwards (1942), Thomas and Pratt (1967), Pratt (1966b, 1971a) and Pratt and Knight (1971); in Tanzania by Van Rensburg (1952); and in Uganda by Masefield (1948). From this work and from practical field experience, it is clear that the effectiveness of fire in bush-control depends on a variety of factors associated with the intensity of the fire and the structure and condition of the plant. These are summarized below.

### Amount of combustible material

Since fire in rangeland is carried mainly by dry grass, a ground cover comprising at least 1 500 kg/ha of dry matter is needed for effective burning. With a discontinuous ground cover, relatively more material is required if the fire is to carry over poorly covered areas. A grass cover in which a large proportion of the fuel is close to the ground usually gives better results than does tall grass with little foliage at ground level; *Themeda* usually burns well; *Panicum* often burns poorly. In South Africa, greatly increased mortality has been obtained in *Acacia mellifera* by piling dry branches or sawdust under the bushes before burning (Donaldson 1966).

### Climatic conditions

The most important climatic factor is atmospheric humidity (Pratt and Knight 1971). When the relative humidity is above 50 per cent, even a dense stand of dry grass will not burn satisfactorily, but when it is below 20 per cent a good burn can be obtained from a patchy cover of partially green herbage. Burning should not be attempted when the humidity is above 40 per cent and, for preference, the figure should be 30 per cent or less. The use of a hygrometer or psychrometer is strongly advised in deciding whether conditions are suitable for burning.

Wind speed is also important. At relatively high humidities a steady breeze is necessary for satisfactory burning, while at low humidities calm conditions are preferable. With a combination of low humidity and strong wind, fire sweeps through the area too rapidly to have maximum effect, and is more likely to get out of control. A third factor is air temperature. Less heat needs to be generated to kill sensitive tissues if the air temperature is already high (Vines 1968).

These three factors normally follow a predictable pattern during the day, so that it is often possible to decide in advance the time of day at which conditions are likely to be most suitable for burning. In many parts of East Africa the best combination of low humidity, low wind speed and high air temperature occurs during the mid to late-morning period.

### Method of ignition

The usual method is to fire the perimeter of the area to be burned, starting on the down-wind side and moving round to finish on the up-wind side. Burning the whole area against a light wind gives a slower moving fire, which can be expected to produce more heat around the trunks or stems of woody plants; but

with a discontinuous grass cover it may be necessary to burn with the wind. Heady (1960) has suggested that the most heat is generated by area ignition — whereby the fire is started simultaneously at numerous points over the entire area — but this seems to apply only under certain favourable fuel conditions (Thomas and Pratt 1967).

### Plant structure and condition

Relatively little is known of the susceptibility to fire of the woody species of East Africa, or of the factors which control fire susceptibility. The position is complicated by the fact that a species may be tolerant of one burning régime and sensitive to another. However, it seems that in most cases tolerance depends either on a thick or fissured bark or on the possession of large root reserves combined with an ability to sprout from below ground (Thomas and Pratt 1967). Woody plants which produce rather few but fast-growing sprouts are usually more tolerant of repeated burning than are plants which produce an abundance of small sprouts. Those with an enlarged root crown are especially tolerant (e.g. *Acacia brevispica*, *Tarchonanthus* and *Premna oligotricha*). Species with a multi-stemmed and spreading form of growth, which prevents the growth of grass near the stems, often manage to keep fire at bay and so may be said to resist fire, though they may not prove to be fire-tolerant should fire ever penetrate this defence.

Plant size is also important in determining susceptibility. Small plants are generally more affected than larger ones, though not always (Pratt and Knight 1971). Although repeated burning tends to keep plants small, fire-tolerant species can usually grow away from the effects of fire if they once pass a certain size.

### Time and frequency of burning

Most burning in East Africa is undertaken at the end of the dry season, when the herbage is at its driest and conditions are most suitable for a hot fire. Although there is little experience locally of earlier burning, there is an obvious danger that, if burning takes place early in the dry season before the soil is dry, the grass will be stimulated to sprout and will succumb to drought before the end of the dry season. In very dry areas, however, where annual grasses predominate, earlier burning may be necessary in order to avoid too much loss of fuel from termites and weathering. For information on the effects of time of burning in central Africa (in *miombo*) see Trapnell (1959), and for West Africa (the Guinea

savanna) see Ramsay and Rose Innes (1963).

In most burning rotations, the interval between burns is from three to six years, which is sufficient to check encroachment in relatively open areas. At Katumani, Kenya, in eco-climatic zone IV, burning every third year checks encroachment sufficiently to maintain open grazing, while under six-yearly burning the density of the woody vegetation increases. To open up denser bushland, more frequent burning is needed. With certain species, such as *Acacia brevispica*, biennial burning seems best; in others, a sequence of three annual fires gives good control (Plate 9a, Thomas and Pratt 1967, Pratt and Knight 1971). However, such régimes cannot be continued for long without serious loss of grazing and possible damage to the grass cover.

In conclusion, it needs to be stressed that fire can often be used profitably in association with other methods of control. With most mechanical methods of control, subsequent burning is needed to remove the debris, if not also to control regrowth. Burning may also be combined with chemical methods. Pratt (1971a) showed that fire after treatment with fenuron resulted in increased mortality in *Acacia drepanolobium*, and it is possible that this effect occurs with woody plants weakened by other types of chemical. A further possibility is to burn prior to chemical treatment, with the objective of applying the chemical when the regrowth has used up the maximum of food reserves from the root and before replenishment has occurred. This has proved to be effective with a number of woody species in the United States of America (Leonard and Harvey 1965).

### Mechanical methods

The use of simple hand tools to cut, ring-bark or uproot woody vegetation has been an essential feature of shifting cultivation in Africa since earliest times (Allan 1965). The same methods of bush-control were employed in the early development of commercial ranching in East Africa. The introduction of tractor-drawn machinery has greatly increased the speed with which trees and shrubs can be cut or uprooted (Bunting *et al* 1955), but the high cost of such equipment relative to the low cost of labour has limited its use in East Africa. Nevertheless sufficient experience of a wide range of machines has been gained to judge their effectiveness under local conditions.

A common feature of most mechanical methods is that subsequent burning is necessary to dispose of the debris. Furthermore, most woody species in most situations regenerate after being cut, whether by



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## Fire and its use in manipulating vegetation

H. F. LAMPREY

*Unesco Man and Biosphere Programme, Kenya Arid Lands Research Station, Unesco,  
P.O. Box 147, Marsabit, Kenya*

Fire is the most important means of manipulating vegetation in most African rangeland plant communities and the greater part of this paper is devoted to the subject of burning. It is based upon several publications and upon my own field experience in East Africa.

In the extensive published literature on the role of fire in the ecology of African savanna vegetation, the following major conclusions appear repeatedly (see Gillon 1983):

- 1) grass fires may be natural or man induced;
- 2) natural fires, usually started by lightning, have probably occurred since the earliest origins of terrestrial vegetation;
- 3) man-induced fires in Africa, whether accidental or deliberate, have occurred for at least 50,000 years (Clark 1959) and for a long period most savanna fires are likely to have been started by man;
- 4) African savanna vegetation is, in varying degrees, adapted to periodic burning, having evolved in association with fire, but has experienced an increased frequency of burning since man learned how to make fire; and
- 5) fire is an important factor influencing short-term successional change in savanna plant communities, and its frequent repetition has probably been a determining factor in the species composition of most savanna vegetation types.

Publications concerned with fire in African rangelands fall mainly into two categories: i) those that deal with the role of fire in savanna ecology and ii) those that deal with the use of fire as a management tool in manipulating vegetation. The former category includes a recent review of existing knowledge by Gillon (1983), who discusses the observations of several authors as well as his own which were made largely in the humid savannas of the Ivory Coast, in West Africa. Hopkins (1983), in another review chapter in the same volume on tropical savannas, discusses specifically the influence of fire upon major successional

processes such as the transition between forest and moist savanna which, under varying fire regimes, has been observed to change in either direction in West Africa. In eastern Africa there appear to be no records of forest boundaries advancing into savanna areas, but there are very many places where the forest edge is receding under the influence of fire in the adjoining grasslands, as will be discussed later in this paper.

The role of fire in East African savanna ecology has been the subject of studies by Glover (1968), Vesey-Fitzgerald (1971) and Spinage and Guinness (1972). The last two specifically concerned fire in national parks and its effects upon the habitats and the large mammal populations. Norton-Griffiths (1979) discussed the combined effects of grazing, browsing and fire upon the vegetation dynamics of the Serengeti National Park where the most urgent park management issue was the relative importance of fire and elephants as agents in the decrease of the tree populations. This author argued conclusively that the frequency and intensity of grass fires were the most important factors affecting tree density. However, the fundamental cause of the increasing impact by fire observed prior to 1962 was the great reduction in the numbers of grazing animals, mainly wildebeest and buffalo, caused by recurrent outbreaks of the virus disease rinderpest, which led to very low utilization of the grasslands. The unused grass provided fuel for fires which burned right across the wooded areas of the park annually. With the eradication of rinderpest from northern Tanzania in the early 1960s, the ungulate populations of the Serengeti increased by 79 per cent and, during the decade 1962-72, the grazing impact increased by 48 per cent, with the result that the extent of grass fires was decreased and the number of young trees that survived fires was increased.

This example of the often complex relationship between fire, grazing and plant succession draws attention to the most important principles in range management discussed in this paper: while grasslands are normally



maintained by periodic burning, such burning can take place only if there is sufficient grass fuel present; heavy grazing may reduce the fuel below the level necessary to support fire; in the absence of periodic fire, woody plants will invade the grassland and eventually form thickets.

The second category of publications on fire in African savannas includes many that deal mainly with the use of fire as a management tool and fire in relation to range management. The most comprehensive discussion is that of West (1965), which covers almost every aspect of the subject and makes reference to 199 publications, the great majority of which relate to southern and central African savanna grasslands.

West introduced one important publication (1963) with the thesis that wooded savanna grasslands (termed *bushveld* in southern Africa) represent a stage in plant succession where the two competing communities of grasses and woody plants exist together in a state of delicate balance. In his own words, "A maelstrom in which the wave of population dominated by the grasses and their associate forbs has met and is clashing with the wave of trees to which it will eventually give way." Writing about the region that includes Zambia and Zimbabwe, he discusses the successional stages through which a savanna grassland progresses towards the final "climax vegetation", which is controlled by the climate. He states that there is no area in the region where the climax vegetation can be grass, but that all the existing grassland is seral with a natural tendency to change towards bush and forest of various types. Thus, all open country, whether it be grassland or open woodland, is maintained in that condition by some factor (or combination of factors) that has prevented or is retarding the country's progress towards bush. The most important retarding factor is fire.

It is evident from the majority of publications on the use of fire in range management that the explicit or implied objective of management has most commonly been the maintenance of grassland and the suppression of woody growth or "bush encroachment". This objective is wholly understandable in cattle and sheep grazing areas. The frequent use of controlled burning is essential in such areas and is the subject of later sections of this paper. However, in the management of wildlife areas in Africa, especially in the national parks, where many of the ungulate species are browsers, a totally different objective exists. It is to maintain a chosen balance of vegetation types that will provide habitats for all the indigenous mammal and

bird species, in addition to promoting diversity in the plant species present. Controlled fire is the means to achieving this objective, but the degree of control necessary to ensure the desired frequency, distribution and intensity of fire is difficult to achieve.

In East Africa several authors have dealt with the practical aspects of management by controlled burning or of experiments in burning for management purposes (Heady 1960; Pratt 1966; Pratt and Knight 1971; Thomas and Pratt 1967; Ross and Harrington 1969; Harrington 1974; Pratt and Gwynne 1977). Information in the following sections is derived from the sources cited above and from personal observations. Except where an author has not been referred to already, information in the sections that follow will not be attributed to specific authors since many observations are common to several authors or are now common knowledge.

#### Causes, distribution and incidence of fires

The great majority of fires in savanna regions occur in grasslands. A fire begun from the burning of a tree or from a domestic fire will spread and cover appreciable areas only where the vegetation is relatively dense and dry. The dessicated grasses of subhumid and semi-arid savanna in the dry seasons which are characteristic of these climatic zones provide the conditions under which most savanna fires occur. In most other vegetation communities where grass is not dominant, fires are rare. However, in the relatively arid regions of northern Kenya, the dwarf shrub *Duosperma eremophilum* locally forms thickets dense enough to support fire in some years.

Nearly all fires in savanna grasslands are started by people. Natural fires occur occasionally, usually started by lightning and usually during the thunderstorms that take place at the very beginning of the rainy seasons when the grass is most combustible. Other causes include spontaneous combustion of accumulated vegetation and sparks produced by falling rocks.

Man has known how to make fire for several millennia but until the introduction of the match, making fire was quite difficult and time-consuming. The ease with which a fire can be started today probably means that fires have become more frequent than they were a century ago.

Fires occur throughout the grasslands and wooded grasslands of tropical Africa where the vegetation provides sufficient fuel to support their spread and where the one or two annual dry seasons are sufficiently prolonged to dry out

the standing grass and herb growth sufficiently to make it combustible. Over very large areas in eastern, central and southern Africa the grasses of the *Acacia* and *Brachystegia* savanna woodlands, as well as the seasonal flood plains, the edaphic grasslands of the East African volcanic ash soils and the montane grasslands and heathlands, burn at intervals of from one to several years.

The areas that experience the most frequent and extensive fires are the subhumid grasslands where the dominant species, most commonly of the genus *Hyparrhenia*, may reach a height of over 3 m and a dry-weight biomass of over 10,000 kg ha<sup>-1</sup>. Such tall grass savanna normally burns annually. Grasslands of the semi-arid regions of East Africa dominated by the genera *Themeda*, *Pennisetum*, *Chloris*, *Digitaria* and *Cymbopogon* and likely to stand approximately 1 m high, with a dry-weight biomass of c. 5,000 kg ha<sup>-1</sup>, commonly burn at intervals of between every one and every three years. The frequency of fire in any area depends of course on the number of times fires are lit, but also upon the area of grassland over which fire can burn without encountering such natural and artificial fire breaks as stream beds and roads. Seasonal swamp grasslands commonly burn annually except in those occasional years when they remain wet and green. The edaphically maintained grasslands of the volcanic ash plains of East Africa occur across climatic and soil gradients where they reach 1 m high at their most productive zones and where annual fires are normal. At the dry end of the range, the ash-soil grasslands remain very short, partly under the influence of intensive grazing by wild and domestic ungulates, and normally do not burn at all. Similarly, increasingly large areas of grassland that experience constant heavy grazing by cattle in the Kajiado and Narok districts, of Kenya, have not produced sufficient grass for many years for a burn to take place.

Towards the drier end of the range of semi-arid grasslands, where mean annual rainfall is less than 350 mm, the perennial grasses are replaced, at least locally, by annual grasses, mainly of the genus *Aristida*, which tend to grow too sparsely to support extensive grass fires. Over very large areas of sub-desert annual grassland in northern and eastern Kenya where the mean annual rainfall is below 250 mm, fires do not normally occur. However, the extensive rangelands of Samburu and Baringo districts, in Kenya, and of the Longido and the Ruvu Valley, in Tanzania, which in living memory have been degraded from productive perennial grasslands to virtually bare soil supporting

*Acacia* thickets, formerly supported grass fires but now never do so.

#### Characteristics of grass fires

A grass fire normally consists of a relatively narrow band of flames, commonly less than 1 m wide, which advances along a front of varying length from a few metres to several kilometres. A fire starting from a single point generally burns rapidly downwind spreading out along an increasingly broad front and creating a fan-shaped burned area behind it. The speed of advance varies according to the strength of the wind; in a moderate breeze it may be approximately 1 m per 10 to 20 seconds in grass 1 m high. The height of the flames increases with the available grass biomass (Rains 1963) but also depends upon the moisture content of the vegetation. The dense dry grass of seasonal flood plains in northern Tanzania burned with flames approximately 40 m high (observed in the Tarangire National Park in 1960).

The temperatures of grass fires vary considerably. Fires that occur early in the dry season, which start when the vegetation is still slightly green, generally are relatively cool. Fires that occur late in the dry season tend to be hot. Fires that reach their maximum intensity during the middle of the day and the afternoon die down during the night and, if dew is present, may go out. If they stay alight during the night, they are normally very low shortly after dawn and can be extinguished relatively easily.

The rise in temperature as the fire front passes a particular point is brief, with the highest temperatures persisting for only a few seconds. At the soil surface the temperature can become very high but it varies greatly from place to place, even between areas two or three metres apart. Several authors give measured temperatures quoted by Gillon (1983); these vary from 35° to 538°C (Hopkins 1965). Inside burning grass tussocks the temperatures have been observed to rise less than temperatures outside (52°–65°C). In grass that is 1.2 to 1.5 m high, the maximum temperature in a burn occurs at 50 cm above the ground where it was measured by several authors at between 500° and 600°C. Above this height, temperatures decrease but remain high up to about 3 m above the surface.

Below the soil surface the temperature rise is relatively small and it decreases rapidly with increasing depth. Just below the soil surface it was found to remain below 60°C. Below 5 cm depth no change in temperature was recorded in Brazilian grasslands (Coutino 1979). The small

rise in temperature that occurs inside grass tussocks and the negligible rise below the ground explains why so many burrowing animals and soil organisms, as well as the underground parts of savanna plants, can tolerate the passage of a grass fire.

Fires vary greatly in their severity. The strength and direction of the wind, the slope, the atmospheric moisture level and the time elapsed since the previous fire also determine the destructive effects of the fire. A fire that burns slowly upwind is more destructive than one that burns rapidly downwind. Grass fires tend to burn uphill and to follow the tops of ridges while leaving the valley bottoms and steeper sides unburnt. The patterns of burning can readily be distinguished in hilly country, where the grass fires gradually burn back woodland and forest edges high up on the ridges, leaving the forest vegetation intact in the valleys and on the lee sides of the hills. As the forest retreats, grassland replaces it, leading to increasing areas of grass, often in the form of intrusive glades within the forest.

#### **Traditional purposes of burning**

Pastoralists light fires during the dry seasons to stimulate early growth from the perennial roots and rhizomes of the grasses in order to obtain forage for the animals before the arrival of the rains. In some areas such burning attracts wildlife so that it can be hunted. Honey hunters start fires when they smoke out bees' nests. Native hunters burn dry vegetation for increased visibility and ease of moving about. Cultivators burn vegetation to clear the land for agriculture.

In more recent times commercial ranchers carry out controlled burning to eradicate woody growth from grasslands, to establish fire breaks and to control livestock parasites. In national parks and other wildlife reserves, controlled fires reduce the risk of extensive uncontrolled fires and enable some manipulation to be carried out on adjusting the balance of the woodland/grassland mosaic. Foresters who protect woodland and forest areas by controlled early burning eliminate the risk of destructive late burns which tend to destroy numerous young trees or to burn them back to ground level.

#### **The influence of fire upon savanna vegetation**

There is general agreement among ecologists that savanna grasslands are not simply adapted to periodic burning but are to a great extent

dependent upon it. It is a common experience in the rangelands of Kenya that grasslands in the semi-arid and subhumid zones that do not burn, unless they are edaphic in origin, change into shrublands and woodlands and may end up as dense thickets of woody vegetation. Such thicket areas are to be found scattered through the rangelands of Kenya and Tanzania, most commonly where former grasslands were heavily grazed and, as a consequence, had insufficient fuel to support fires. However, there are in some areas grazing lands that remain unburnt through deliberate protection from fire and that are becoming progressively overgrown by tree and shrub vegetation. Examples can be seen in several of the commercial ranches on the Laikipia Plains. There it is apparent that the failure to leave parts of the ranches ungrazed each year has prevented sufficient grass growth to support the fire necessary to control the tree growth. One reason for preventing fires in such areas is the fear that a fire may get out of control and burn badly needed pasture. Another reason is a purely economic one: the rotational burning system that is necessary to control bush encroachment on ranches necessitates leaving at least a quarter of the ranch ungrazed (and therefore unproductive) for a year. By short-term standards, this sacrifice of income may be unacceptable, but seen in the long-term, it is almost certainly more economical to practise the rotation and control the bush encroachment.

In general, frequent burning of savanna vegetation suppresses trees and shrubs and encourages grasses. This is particularly true if the fires occur late in the dry season when the grasses are dead hay above the ground and have transferred all their nutrient material to their underground storage organs. In this condition the grass plants remain unharmed by even the hottest fires. At the beginning of the following rains, vigorous growth takes place from the root and rhizome bases of the grasses. In the case of the annual grasses, which die completely during the dry season, the seeds which carry the species into the next year remain largely unharmed when they fall into small cracks in the soil. The *Aristida* species have seeds that actively penetrate the soil with their barbed points and their long awns moved by the wind, and that settle below the level at which a fire can affect them.

Although most savanna plants are adapted to withstand fire, they vary in their tolerance to it. Savanna trees and shrubs are generally resistant to fire when they are mature and, although they may have all their foliage and the year's new growth burnt off by hot fires, are likely to

survive and to renew their growth in the following rainy season. Seedling and sapling trees which are likely to have their stems and crowns at the level of the hottest part of the grass fire are almost invariably burnt back to ground level like the grasses among which they have been growing. To varying degrees, the tree and shrub species tolerate this treatment and produce new shoots from their root-stocks. Several of the *Acacia* species will survive annual burning and browsing by ungulate animals for as many as 30 years, increasing the size of their roots with each year but not growing in height. Whole woodlands remain in this suppressed condition for many years until the occurrence of a favourable series of years when relatively low rainfall, combined with heavy grazing, may reduce grass growth to a level at which fire cannot spread. Under these conditions young trees and shrubs may be given the opportunity to grow above the height vulnerable to fire and to continue to grow into mature trees. As mature trees they are protected from fires by the resistant and insulating properties of their bark and also by the fact that the bulk of their above ground growth is above the hottest part of the fire.

Most fires that occur through casual or deliberate action take place late in the dry season when the vegetation is dry and relatively combustible. Such fires are generally hot and have the most destructive impact upon vegetation, particularly upon woody plants. The exception to this, as discussed above, are the grasses, which are not normally harmed by hot fires, since it is the dead material that burns.

In contrast to hot fires which occur late in the dry season, cool fires can be started when the vegetation is still green. Such early fires have a very different effect on grasses and woody plants from that of late hot fires. Although early fires burn with relatively low intensity, they can be very damaging to perennial grasses because they destroy the nutrient material still present in the aerial parts of the plant and curtail the growth and the storage of nutrients which prepare the plant for dormancy in the dry season and its subsequent regrowth at the beginning of the next rainy season. Repeated early fires cause perennial grasslands to degrade, with increasing replacement of the grasses by annual herbs and by woody plants and with a reduction in the productivity of the pasture.

Early fires are generally beneficial to young trees and shrubs. First, they tend to preclude the occurrence of the more destructive late fires; second, they reduce the growth of the grasses with which the small trees have to compete for

water and soil nutrients. For these reasons, early burning is normally employed by foresters to encourage the growth of young trees. It is also employed for the same purpose in national parks where tree growth is desired in order to increase the woodland element of savanna habitats. Early burning was used in the Serengeti National Park during the early 1970s as a means of reducing the frequency and extent of late hot fires when it was realized that there was a progressive reduction of the tree populations over very large areas largely due to the high incidence of grass fires.

Despite the general observation that late hot fires are not seriously harmful to grasses, two authors (Brockington 1961; Skovlin 1972) noted that burning retards the development of most grass species in dry savannas since it accentuates the effects of seasonal drought periods. The absence of burning allows the accumulation of dead material which acts as a mulch, insulating the soil surface from the desiccating action of sun and wind and helping to conserve soil moisture and nutrients.

Since certain plants are more tolerant of fire than others, repeated burning of a plant community obviously tends to eliminate the less tolerant species and to favour the more tolerant. Over very large areas of the semi-arid savannas of eastern Africa, the fire tolerant grass *Themeda triandra* is dominant. Annual fires in such savannas virtually ensure almost pure stands of *Themeda*, although often with a lower storey of small annual grasses such as *Microchloa*. Less frequent burning tends to allow the less fire-tolerant species to compete successfully with the *Themeda* and to increase in density. Exclusion of fire effectively removes any advantage for *Themeda*, which is then progressively replaced by a variety of species that are less fire-tolerant but have greater vigour in the absence of fire.

In the semi-arid savannas of eastern Africa, grasslands are maintained by periodic burning which suppresses trees and shrubs. In grazing lands where fire does not occur or is infrequent, the woody plants that grow and that may eventually become dominant are most commonly *Acacia* species. Which species invades depends upon the climatic zone of the savanna in question. Near the coast it is likely to be *A. zanzbarica*; on the extensive plateau of Kapiti Plain at 1,600 m above sea level, the commonest invader is *A. drepanolobium*; on the higher grasslands, at 2,000 m, it is *A. hockii*. Highland pastures at 2,500 m are frequently invaded by thickets of *A. lahai*.

A combination of heavy grazing and infrequent burning normally accelerates the growth

of trees. Grasslands that are consistently heavily grazed at the 1,300-m level may be invaded by the mimosid shrub *Dichrostachys cineraria*, which is capable of forming dense thickets. Over wide areas of the Rift Valley and Narok District the commonest species occurring as an invader in grasslands is *Tarchonanthus camphoratus*.

When such bush encroachment has taken place through a lack of burning, the invading trees and shrubs may be very difficult to remove.

#### Burning as a management tool

In the previous section, reference was made to the very different effects of early and late burning in savanna grasslands and woodlands. In the use of fire as a means of manipulating vegetation, the time of burning and several other considerations, particularly the means to achieve adequate control of fires, will depend upon the objective of the management. As already discussed, the two commonest objectives for management by burning are: 1) the suppression of woody growth in grasslands and 2) the protection of woodland and forest against destructive hot fires.

The practical application of controlled burning to maintain grazing land free of woody plants is described by Pratt and Gwynne (1977), and includes the method of ignition, the direction of burning in relation to the wind and the timing and frequency of burning. Provided that there is enough fuel, a slow burn against the wind is most effective since it subjects the trees and shrubs to heat for longer periods than fires that move with the wind. Fires that can be started at several points at once and produce area ignition are particularly effective (Heady 1960), but this practice depends upon certain favourable fuel conditions and may be difficult to achieve (Thomas and Pratt 1967).

There is general agreement that pastures subject to bush encroachment should be burnt late in the dry season and at a frequency of once every three or four years. In practice the frequency of burning can be varied to suit the conditions prevailing in the grassland concerned. In relatively wet years when grass production is high, the subsequent dry season burn will be particularly hot and may not need to be repeated for as long as five years. In a series of dry years, with low grass production, it may be advantageous to burn as frequently as every two years in order to control woody growth. In droughts lasting several years grass growth may be insufficient to support fires and the small trees and shrubs may be able to make slow

progress in their own growth.

In carrying out controlled burning, it is essential that the fire should be contained within the area intended to be burnt and not spread into adjoining grasslands that are not to be burnt. This is normally achieved by the use of existing fire-breaks such as roads and tracks and by cutting fire-break traces with rotary mowers. Fire-breaks are also prepared by igniting green grass along the sides of tracks with sprayed diesel fuel. The burn lines obtained in this way are probably the most effective kind of fire-break. The width of the fire-break must be sufficient to prevent fire being carried across into adjoining areas by wind-blown burning material. A width of about 15 to 20 m is normally considered a reasonable compromise between practicability and effectiveness.

Early burning to provide fire-breaks against hot fires late in the dry season is practised in the national parks but is very difficult to achieve on a large scale. Experience in the Serengeti National Park in the late 1960s and early 1970s showed that the period during which the grass would ignite and burn slowly at any one place was as short as a week or even only three days. One day too early, the grass would be too green to burn and one day too late, it would burn too readily and a hot burn would result. Since the drying out process moved progressively across the park over a period of one or two weeks, the systematic early burning programme became a carefully judged operation in which the team of burners tried to be at the right place at the right time. Normally, only partial success was achieved each year. Nevertheless, the early burning programme did effectively reduce the incidence of hot fires.

#### Conclusion

Fire is the commonest and, under most circumstances, the most effective tool in the management of vegetation in the semi-arid and subhumid rangelands of Kenya. Several other management methods are described in the literature (see Pratt 1966; Pratt and Gwynne 1977; Pratt and Knight 1971). These include chemical treatment, mechanical clearing and the use of controlled grazing and browsing by domestic animals. In the control of bush and tree encroachment on grazing land, the extensive use of chemical and mechanical methods appears to be unduly expensive and these methods are apparently used only exceptionally. The employment of camels to reduce the density of woody vegetation on cattle ranches is successful on some ranches in the Laikipia region of Kenya (J. Evans, personal

communication). The controlled herding of goats is a very successful means of reducing certain woody herbs (e.g., *Aspilia* spp.) that tend to increase with heavy grazing in cattle pasture in many parts of upland Kenya.

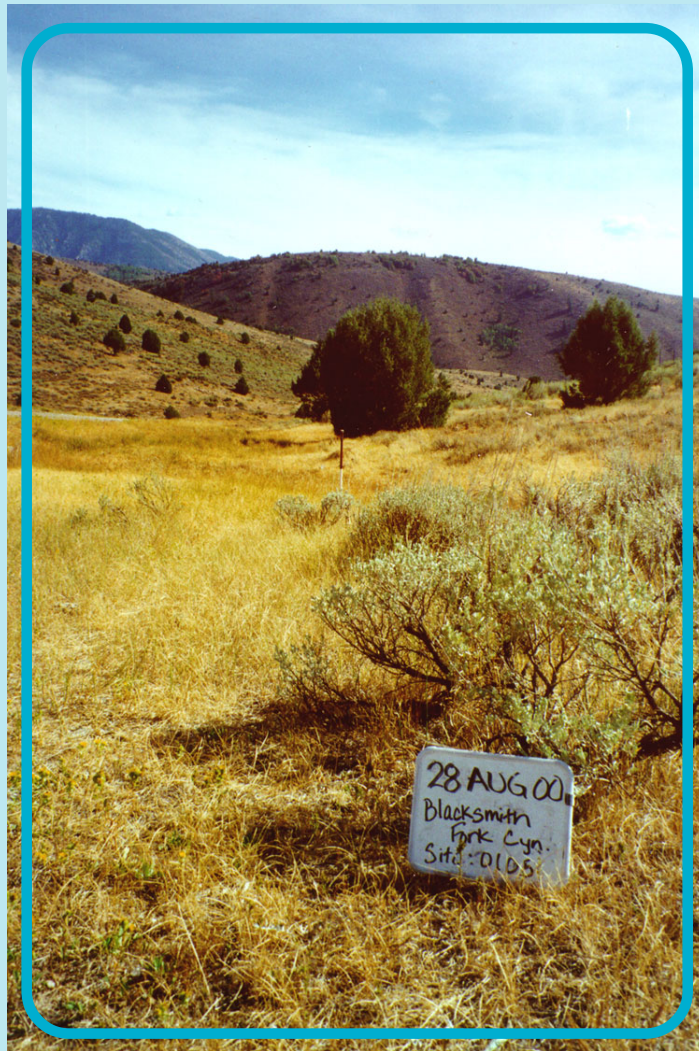
The importance of fire in rangeland management should be recognized and it is clear that the study of burning should figure prominently in teaching range management and range ecology at technical and professional levels. Used wisely, it can help to modify rangeland for several desired purposes, both on livestock pastures and in the national parks and wildlife reserves. Frequent uncontrolled fires can be deleterious in rangelands and may be hazardous.

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# Repeat Photography Monitoring Made Easy



**G. Allen Rasmussen and Kathy Voth**



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NR504

## Photo Monitoring Made Easy

How often have you said or heard, "This area looks so much better than it was back...." The problem occurs when other people are not sure they can believe what they hear. They may still see problems and wonder to themselves how truly interested managers are in solving them. In addition, for those who have not been around to see improvements, the slow rate at which nature changes can make it seem that managers are doing nothing.

So what can you do? You've heard it for years - MONITOR! Rather than making your life more difficult, good monitoring can actually simplify it. Since most of us remember only the very best and very worst, our memories often fail us when it comes to gradual changes over longer periods of time. With the data collected and stored, you no longer have to rely on your memory. Your data are also more useful than your memory in describing what you saw, and is more readily accessible to interested public or managers who may follow you. Your data can provide you with concrete proof of successes and help you identify management strategies that did or did not work. Aldo Leopold once said "If you learn to read the land, I have no fear what you will do to the land." Your monitoring data can demonstrate how you read the land, reducing others' fear of what you might do.

Professional land managers have used monitoring as the basis for making decisions as varied as livestock movement to wildlife harvest rates and for determinations of water quality and ecosystem health. The Society for Range Management has defined monitoring as the orderly collection, analysis and interpretation of data to evaluate progress toward stated goals (1989). The amount of time and expertise this implies scares many people away. However, it is really not that complicated. At the most basic level monitoring is defined as "to watch, observe or check on for a specific purpose" (Webster 1983). All you are required to do is to look, to pay attention to what is happening and to record your observations in some way.

There are many monitoring techniques. Here we will discuss one of the simplest, cheapest and quickest methods -- Repeat Photography. By following the easy steps outlined here, you will collect data and record your interpretations over time to provide proof of change and management efforts. We will cover how to correctly take a photo, how to file it to ensure you can find it and know what it means, and how to record observations and interpretations of the monitoring site.



## Step 1: Get the Equipment

Your equipment must include:

- 1) Camera
- 2) Film
- 3) Photo Board
- 4) Reference pole
- 5) Evaluation forms
- 6) Notebook

**Camera:** There are numerous cameras on the market and any will work. The instamatic cameras are easy to use and very cheap in the short run. If you use a more advanced 35-mm camera, most now have an option to put the date right on the picture. The same is true for the newer digital cameras. If you have a computer system, digital photos may prove to be the least expensive over time.

**Film:** Use color print film. Typically 100 or 200 speed film works best in outdoor, sunny settings.

**Photo Board:** Placing as much information in the picture as possible eases record keeping in the future. Your photo board will appear in every picture you take so that you can be sure the photo includes the date and location of the monitoring site. Your photo board can be an inexpensive white board, or a clipboard with a plastic sheet, or even just a sheet of blank paper. All will allow you to write the appropriate information, take the picture and then move on to the next site.

**Reference Pole:** Your reference pole gives a sense of scale in your photograph. It allows you and others to see changes in the vegetation height and structure over time. Your reference pole should be 1 meter long. A piece of PVC pipe works well. Paint the bottom half red. Duct tape wrapped in the middle makes a good dividing line. The two colors are an important part of making it easy to estimate vegetation height. Some people also attach a stake to the bottom of the pole so it is easier to stick into the ground.

**Evaluation Forms:** This form is the place you will put your printed photo and your evaluations of the site from your visit. A form with printed questions or observation requests can jog your memory to ensure you collect the same information every time.

**Notebook:** With one place to store your photos and your evaluation sheets, you'll have quicker access to your information in the future. Using a notebook also makes it easier to carry photos from the past year into the field with you so you can be sure you're repeating photos at the same locations every time. A three ring binder works well. We suggest attaching your photos to your evaluation sheets (see the last page for an example).

## Step 2: Choose a Location

Your photo monitoring will be most useful if you select "Key Areas" to monitor. A key area is representative of the area you are managing and acts as an indicator of changes that may be taking place. The greater the variety in your terrain, the larger the number of key areas you will need to properly represent the area being monitored. Keep these guidelines in mind when selecting your photo monitoring location:



**Equipment Needed.**

1. Choose a spot you will have time to visit and monitor.

Pick areas that are high priority for your operation and add others over time.

2. Be sure that the area is representative of a larger area.

Choosing areas where livestock congregate (watering points or fence lines) or where livestock never graze will give you important comparisons. However, these areas may not adequately represent the larger area and how your management affects it over time.

3. Select enough key areas to adequately represent the area you manage.

An advantage of having more than one key area is that it ensures small local events, such as fires or floods, do not misrepresent conditions in the larger area.

4. Comparison photo stations in grazed and ungrazed areas can help you evaluate the effects of grazing.

Be sure that the sites are similar in soils, topography and precipitation.

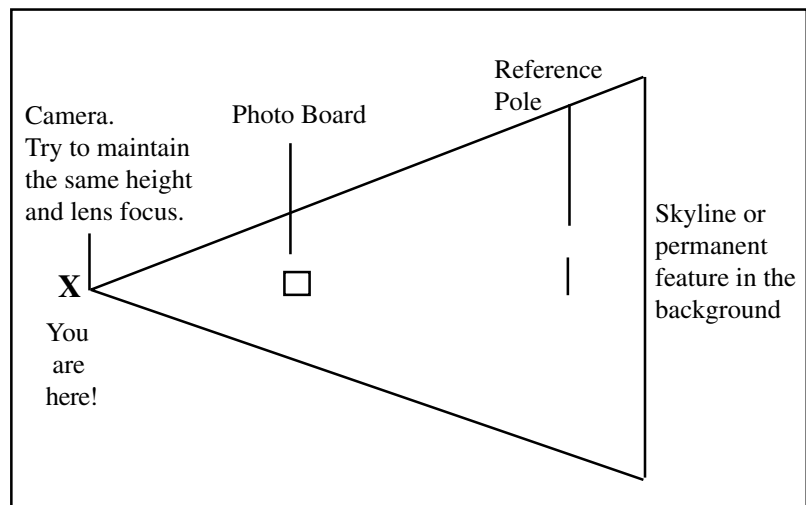
If you would like more information on how to pick key areas, see Bureau of Land Management, 1996, Sampling Vegetation Attributes, Interagency Technical Reference BLM/RS/ST-96/002.

### Step 3: Take the Picture

The type of camera, film and lens are not as important as how you take the picture. Every picture you take should include the following, in order of importance:

- 1) Landmark
- 2) Photo Board
- 3) Reference Pole

Figures 1 - 3 show examples of monitoring photographs that range from useful to not useful.



**Setting up the Picture**

**Landmark:** A distinctive, permanent landmark is critical if you or others after you are going to find the photo point in the future. Repeating your photo at the same site on an ongoing basis allows you to use the photo to analyze and demonstrate what your management has done. By going to the same point every year, you also cannot be accused of simply picking points to your advantage.

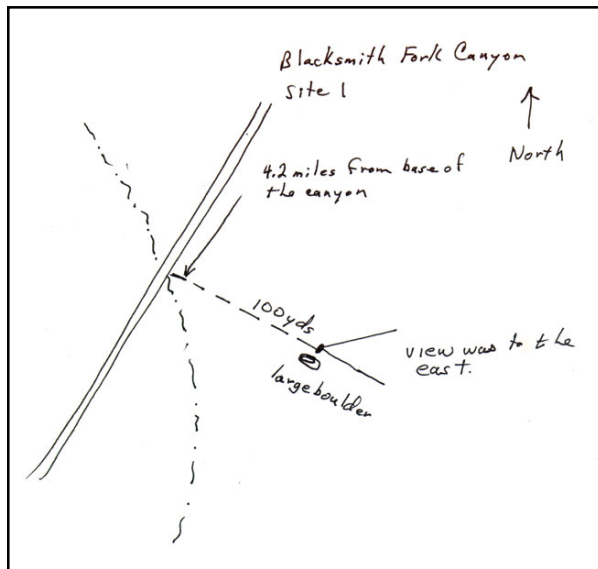
As you look through your camera's viewfinder check to be sure the frame includes a skyline. It can be particularly difficult to include a skyline when you are photographing a riparian area. Are there rock outcrops, mountain slopes, or other geologic features that will remain the same over long periods of time? Adjust your site until you are sure that your photo will include a landmark that you can find again and again. This will also help others to know they are looking at the same site.

**Photo Board:** After writing the date and the location of the monitoring site on your photo board, place it in the foreground of your picture. Check through your viewfinder again. Is the board legible? Be sure the sun's glare will not prevent you from reading the information on the board once the photo has been printed. With the photo board visible, check to see that your landmarks are also still in the frame.

**Reference Pole:** To make it easier to interpret the picture in the future, the reference pole should be placed the same distance from the point of origin every time. Because your photo board is in the photo's foreground, it can easily be used as the point of origin. Fifty feet from the point of origin is most commonly used to locate the reference pole. In many areas, such as a riparian area, willows can fill in over time making the pole difficult to see, so it might have to be moved forward over time. If the pole is moved, be sure to note this as part of your site observations.

With the reference pole in place, look through your viewfinder one more time. If you can see your landmark, the words on your photo board and the reference pole you're ready to shoot.

## Step 4: Record Your Site Evaluation



Site Map Example

Take out your evaluation forms and write down your interpretation. It does not need to be a long academic write up; just a few words about what you see happening.

### For example:

*"Sagebrush seedlings are starting to show. I should start thinking about reburning this area in the next 5 years or so!"*

*"Grasses are becoming more dominant. I will try to adjust season of use to an early part of year to get the sedges back."*

*"Sagebrush has increased and grass cover is declining. I am seeing lots of bare ground and worry about future erosion."*

can use. In some cases you might want to install a post or pin at the site to help you be sure you take the photo from the same point each time.

To help you remember each location, include a map to the site on your first evaluation form. See the last page for an example of an evaluation form you

## Step 5: Store the Picture and Data

The finishing steps include getting your photos developed and placing them in your notebook along with the evaluation sheets. This is the simplest method, though some people actually use computer systems to store data and photos. Please don't use the storage method used by most folks in a hurry, the standard "it's in the cab of my truck somewhere" filing system shown here.



Typical filing system used by many managers

## Step 6: Repeat the Process

Once you've set up your key areas and have taken your first photos and recorded your observations and evaluations, don't stop. Do this every year. Take photos at about the same time of year. After all, what can you really tell about a site if one photo was taken in the spring and the next year's was taken in the fall? Try to use the same camera lens, film type and shutter speed each time.

## General Recommendations

To make the most of your repeat photography monitoring, be sure it includes the following:

1. A good photo with:
  - Skyline or permanent features for easy relocation
  - Reference pole placed the same distance from the origin point
  - Photo board with date and location written on it
2. Written notes concerning the use and events on the site.
3. Your interpretation of the management effects on the site.
4. A storage system for your photos and notes.
5. Repetition of the process over time.



Dry Valley 1940, Bureau of Land Management photo



1998, Earl Hindley photo

## Use of Historic Photos

Old family albums, historic records at the courthouse, and even the library are additional sources for photos you can use to tell a story about your the management of your area. Look for old photos that have some identifiable feature, maybe from a family picnic, or a round-up. By finding that location today, and putting yourself in the same location as the original photographer, you can take a picture that will show conditions today. The examples shown here are from "A Photographic History of Vegetation and stream Channel Changes in San Juan County, Utah" by Hindley, Bowns et al.



**Figure 1. Four examples of photographs that have everything needed for monitoring changes.** They each have the date, location, a reference pole, and some type of permanent feature that can be recognized. Note how the background skyline makes it easier to find these sites in the future.







**Figure 2. These photographs are less useful.** All have the date, location and reference pole which make them very useful for monitoring. However, because there is no permanent feature or a distinguishable skyline, it will be difficult, or impossible to relocate them.





**Figure 3. These photographs are the least useful for monitoring.** They are nice landscape pictures but do not contain the date, location or a reference pole. These are very difficult to use for monitoring, and then only by the person who took the original photo. To make them more usable, they should be attached to a sheet with the date and location. A map of how to find the site would be valuable as well.

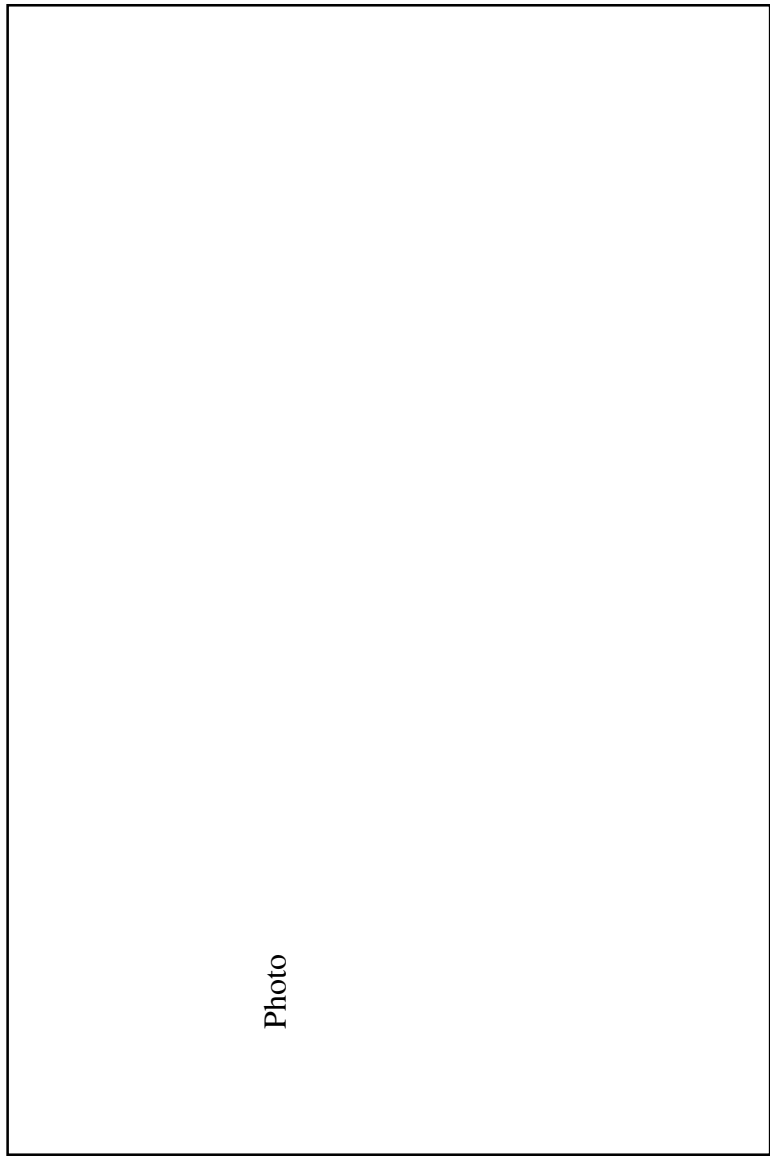
### Evaluation Sheet

Date: \_\_\_\_\_

Location: \_\_\_\_\_

Map to the site \_\_\_\_\_

Photo



What happened in last year? (grazing, type of animal, wildlife, burn, management action etc.)

What are management impacts since the previous photo?



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Forest Service

Intermountain  
Forest and Range  
Experiment Station  
Ogden, UT 84401

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# Aids to Determining Fuel Models For Estimating Fire Behavior

Hal E. Anderson



**HAL E. ANDERSON** has been project leader of the Fuel Science Research Work Unit since 1966. He joined the staff of Intermountain Station's Northern Forest Fire Laboratory at Missoula, Mont., in 1961. He served as project leader of the fire physics project from 1962 to 1966. Prior to employment with the Forest Service, he was with the General Electric Co. and worked on thermal and nuclear instrumentation from 1951 to 1961. His B.S. degree in physics was obtained at Central Washington University in 1952.

### RESEARCH SUMMARY

This report presents photographic examples, tabulations, and a similarity chart to assist fire behavior officers, fuel management specialists, and other field personnel in selecting a fuel model appropriate for a specific field situation. Proper selection of a fuel model is a critical step in the mathematical modeling of fire behavior and fire danger rating. This guide will facilitate the selection of the proper fire behavior fuel model and will allow comparison with fire danger rating fuel models.

The 13 fire behavior fuel models are presented in 4 fuel groups: grasslands, shrublands, timber, and slash. Each group comprises three or more fuel models; two or more photographs illustrate field situations relevant to each fuel model. The 13 fire behavior fuel models are cross-referenced to the 20 fuel models of the National Fire Danger Rating System by means of a similarity chart. Fire behavior fuel models and fire danger rating fuel models, along with the fire-carrying features of the model and its physical characteristics, are described in detail.

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## INTRODUCTION

During the past two decades in the United States, the USDA Forest Service has progressed from a fire danger rating system comprising two fuel models (USDA 1964), to nine models in 1972 (Deeming and others 1972), and to 20 models in 1978 (Deeming and others 1977). During this time the prediction of fire behavior has become more valuable for controlling fire and for assessing potential fire damage to resources. A quantitative basis for rating fire danger and predicting fire behavior became possible with the development of mathematical fire behavior models (Rothermel 1972). The mathematical models require descriptions of fuel properties as inputs to calculations of fire danger indices or fire behavior potential. The collections of fuel properties have become known as fuel models and can be organized into four groups: grass, shrub, timber, and slash. Fuel models for fire danger rating have increased to 20 while fire behavior predictions and applications have utilized the 13 fuel models tabulated by Rothermel (1972) and Albin (1976). This report is intended to aid the user in selecting a fuel model for a specific area through the use of photographic illustrations. A similarity chart allows the user to relate the fire behavior fuel models to the fire danger rating system fuel models. The chart also provides a means to associate the fire danger rating system fuel models with a photographic representation of those fuel types.

## HOW FUEL MODELS ARE DESCRIBED

Fuels have been classified into four groups—grasses, brush, timber, and slash. The differences in fire behavior among these groups are basically related to the fuel load and its distribution among the fuel particle size classes. This can be illustrated by the shift in size class containing the maximum fraction of load when considering the four fuel groups shown in figure 1. Notice that the frac-

tion of the total load in the less than ¼-inch (0.6-cm) size class decreases as we go from grasses to slash. The reverse is true for the 1- to 3- inch (2.5- to 7.6-cm) material. In grasses, the entire fuel load may be herbaceous material less than one fourth inch (0.6 cm), but grass may include up to 25 percent material between one-fourth and 1 inch (0.6 and 2.5 cm) and up to 10 percent material between 1 and 3 inches (2.5 cm and 7.6 cm). Each fuel group has a range of fuel loads for each size class, with maximum fuel load per size class approximately as shown in figure 1.

Fuel load and depth are significant fuel properties for predicting whether a fire will be ignited, its rate of spread, and its intensity. The relationship of fuel load and depth segregates the 13 fuel models into two distinctive orientations, with two fuel groups in each (fig. 2). Grasses and brush are vertically oriented fuel groups, which rapidly increase in depth with increasing load. Timber litter and slash are horizontally positioned and slowly increase in depth as the load is increased. Observations of the location and positioning of fuels in the field help one decide which fuel groups are represented. Selection of a fuel model can be simplified if one recognizes those features that distinguish one fuel group from another.

The 13 fuel models (table 1) under consideration are presented on page 92 of Albin's (1976) paper, "Estimating Wildfire Behavior and Effects." Each fuel model is described by the fuel load and the ratio of surface area to volume for each size class; the depth of the fuel bed involved in the fire front; and fuel moisture, including that at which fire will not spread, called the moisture of extinction. The descriptions of the fuel models include the total fuel load less than 3 inches (7.6 cm), dead fuel load less than one-fourth inch (0.6 cm), live fuel load of less than one-fourth inch (0.6 cm), and herbaceous material and fuel depth used to compute the fire behavior values given in the nomographs.

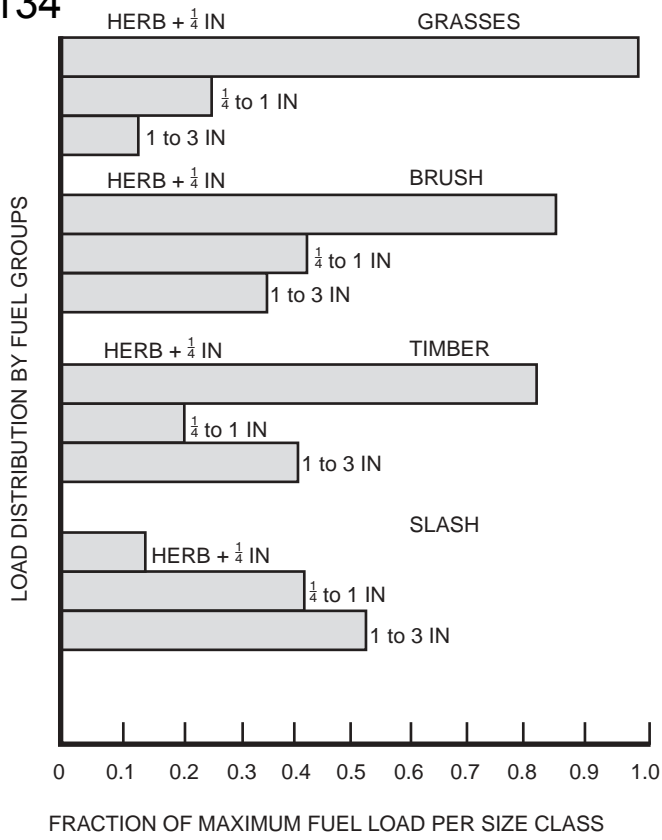


Figure 1. — Distribution of maximum fuel load by size class for each of the four general fuel groups. Note the shift in less than 1/4-inch (0.6-cm) and 1- to 3-inch (2.5- to 7.6-cm) material

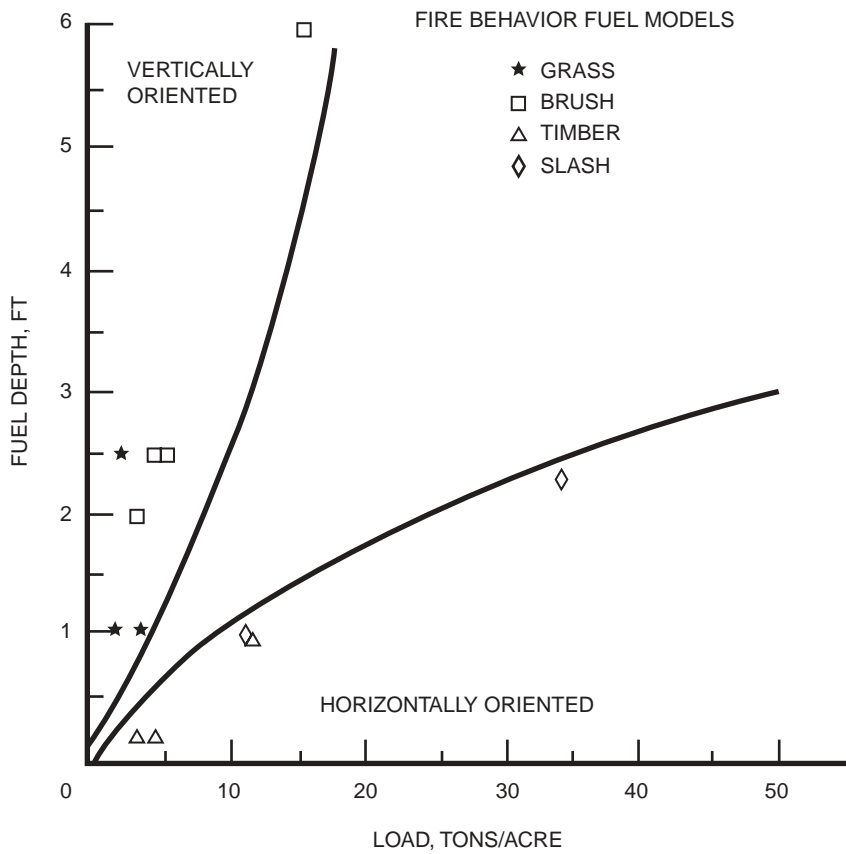


Figure 2. — The four general fuel groups are oriented in two basic directions: vertically, as in grasses and shrubs, and horizontally, as in timber, litter, and slash.

Table 1. — Description of fuel models used in fire behavior as documented by Albini (1976)

Fuel model	Typical fuel complex	Fuel loading				Fuel bed depth	Moisture of extinction dead fuels
		1 hour	10 hours	100 hours	Live		
		-----Tons/acre-----				Feet	Percent
<b>Grass and grass-dominated</b>							
1	Short grass (1 foot)	0.74	0.00	0.00	0.00	1.0	12
2	Timber (grass and understory)	2.00	1.00	.50	.50	1.0	15
3	Tall grass (2.5 feet)	3.01	.00	.00	.00	2.5	25
<b>Chaparral and shrub fields</b>							
4	Chaparral (6 feet)	5.01	4.01	2.00	5.01	6.0	20
5	Brush (2 feet)	1.00	.50	.00	2.00	2.0	20
6	Dormant brush, hardwood slash	1.50	2.50	2.00	.00	2.5	25
7	Southern rough	1.13	1.87	1.50	.37	2.5	40
<b>Timber litter</b>							
8	Closed timber litter	1.50	1.00	2.50	0.00	0.2	30
9	Hardwood litter	2.92	.41	.15	.00	.2	25
10	Timber (litter and understory)	3.01	2.00	5.01	2.00	1.0	25
<b>Slash</b>							
11	Light logging slash	1.50	4.51	5.51	0.00	1.0	15
12	Medium logging slash	4.01	14.03	16.53	.00	2.3	20
13	Heavy logging slash	7.01	23.04	28.05	.00	3.0	25

The criteria for choosing a fuel model includes the fact that the fire burns in the fuel stratum best conditioned to support the fire. This means situations will occur where one fuel model represents rate of spread most accurately and another best depicts fire intensity. In other situations, two fuel conditions may exist, so the spread of fire across the area must be weighted by the fraction of the area occupied by each fuel. Fuel models are simply tools to help the user realistically estimate fire behavior. The user must maintain a flexible frame of mind and an adaptive method of operating to totally utilize these aids. For this reason, the fuel models are described in terms of both expected fire behavior and vegetation.

The National Fire Danger Rating System (NFDRS) depends upon an ordered set of weather records to establish conditions of the day. These weather conditions along with the 1978 NFDRS fuel models are used to

represent the day-to-day and seasonal trends in fire danger. Modifications to the fuel models are possible by changes in live/dead ratios, moisture content, fuel loads, and drought influences by the large fuel effect on fire danger. The 13 fuel models for fire behavior estimation are for the severe period of the fire season when wildfires pose greater control problems and impact on land resources. Fire behavior predictions must utilize on-site observations and short term data extrapolated from remote measurement stations. The field use situation generally is one of stress and urgency. Therefore, the selection options and modifications for fuel models are limited to maintain a reasonably simple procedure to use with fire behavior nomographs, moisture content adjustment charts, and wind reduction procedures. The NFDRS fuel models are part of a computer data processing system that presently is not suited to real time, in-the-field prediction of fire behavior.



**FUEL MODELS DESCRIPTIONS**  
**Grass Group**

**Fire Behavior Fuel Model 1**

Fire spread is governed by the fine, very porous, and continuous herbaceous fuels that have cured or are nearly cured. Fires are surface fires that move rapidly through the cured grass and associated material. Very little shrub or timber is present, generally less than one-third of the area.

Grasslands and savanna are represented along with stubble, grass-tundra, and grass-shrub combinations that met the above area constraint. Annual and perennial grasses are included in this fuel model. Refer to photographs 1, 2, and 3 for illustrations.

This fuel model correlates to 1978 NFDRS fuel models A, L, and S.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	0.74
Dead fuel load, 1/4-inch, tons/acre	.74
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	1.0



Photo 1. Western annual grasses such as cheatgrass, medusahead ryegrass, and fescues.

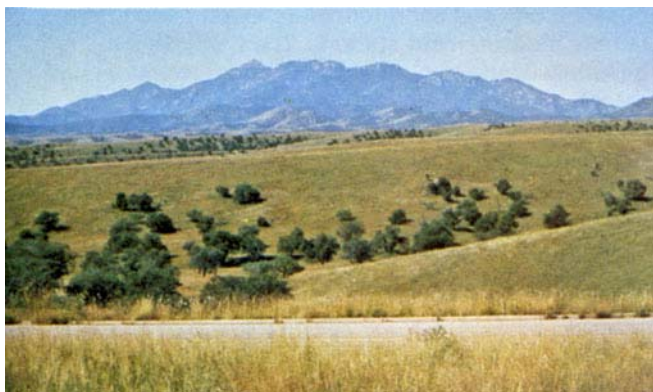


Photo 2. Live oak savanna of the Southwest on the Coronado National Forest.



Photo 3. Open pine—grasslands on the Lewis and Clark National Forest.



**Fire Behavior Fuel Model 2**

Fire spread is primarily through the fine herbaceous fuels, either curing or dead. These are surface fires where the herbaceous material, in addition to litter and dead-down stemwood from the open shrub or timber overstory, contribute to the fire intensity. Open shrub lands and pine stands or scrub oak stands that cover one-third to two-thirds of the area may generally fit this model; such stands may include clumps of fuels that generate higher intensities and that may produce firebrands. Some pinyon-juniper may be in this model. Photographs 4 and 5 illustrate possible fuel situations.

This fuel model correlates to 1978 NFDRS fuel models C and T.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	4.0
Dead fuel load, 1/4-inch, tons/acre	2.0
Live fuel load, foliage, tons/acre	0.5
Fuel bed depth, feet	1.0

Photo 4. Open ponderosa pine stand with annual grass understory.



Photo 5. Scattered sage within grasslands on the Payette National Forest.



**Fire Behavior Fuel Model 3**

Fires in this fuel are the most intense of the grass group and display high rates of spread under the influence of wind. Wind may drive fire into the upper heights of the grass and across standing water. Stands are tall, averaging about 3 feet (1 m), but considerable variation may occur. Approximately one-third or more of the stand is considered dead or cured and maintains the fire. Wild or cultivated grains that have not been harvested can be considered similar to tall prairie and marshland grasses. Refer to photographs 6, 7, and 8 for examples of fuels fitting this model.

This fuel correlates to 1978 NFDRS fuel model N.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	3.0
Dead fuel load, 1/4-inch, tons/acre	3.0
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	2.5

Fires in the grass group fuel models exhibit some of the faster rates of spread under similar weather conditions. With a windspeed of 5 mi/h (8 km/h) and a moisture content of 8 percent, representative rates of spread (ROS) are as follows:

<b>Model</b>	<b>Rate of spread <i>Chains/hour</i></b>	<b>Flame length <i>Feet</i></b>
1	78	4
2	35	6
3	104	12

As windspeed increases, model 1 will develop faster rates of spread than model 3 due to fineness of the fuels, fuel load, and depth relations.



Photo 6. Fountaingrass in Hawaii; note the dead component.



Photo 7. Meadow foxtail in Oregon prairie and meadowland.



Photo 8. Sawgrass "prairie" and "strands" in the Everglades National Park, Fla.



**Shrub Group**

**Fire Behavior Fuel Model 4**

Fires intensity and fast-spreading fires involve the foliage and live and dead fine woody material in the crowns of a nearly continuous secondary overstory. Stands of mature shrubs, 6 or more feet tall, such as California mixed chaparral, the high pocosin along the east coast, the pinebarrens of New Jersey, or the closed jack pine stands of the north-central States are typical candidates. Besides flammable foliage, dead woody material in the stands significantly contributes to the fire intensity. Height of stands qualifying for this model depends on local conditions. A deep litter layer may also hamper suppression efforts. Photographs 9, 10, 11, and 12 depict examples fitting this fuel model.

This fuel model represents 1978 NFDRS fuel models B and O; fire behavior estimates are more severe than obtained by models B or O.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	13.0
Dead fuel load, 1/4-inch, tons/acre	5.0
Live fuel load, foliage, tons/acre	5.0
Fuel bed depth, feet	6.0

Photo 10. Chaparral composed of manzanita and chamise near the Inaja Fire Memorial, Calif.



Photo 9. Mixed chaparral of southern California; note dead fuel component in branchwood.



Photo 11. Pocosin shrub field composed of species like fetterbush, gallberry, and the bays.



Photo 12. High shrub southern rough with quantity of dead limbwood.



**Fire Behavior Fuel Model 5**

Fire is generally carried in the surface fuels that are made up of litter cast by the shrubs and the grasses or forbs in the understory. The fires are generally not very intense because surface fuel loads are light, the shrubs are young with little dead material, and the foliage contains little volatile material. Usually shrubs are short and almost totally cover the area. Young, green stands with no dead wood would qualify: laurel, vine maple, alder, or even chaparral, manzanita, or chamise.

No 1978 NFDRS fuel model is represented, but model 5 can be considered as a second choice for NFDRS model D or as a third choice for NFDRS model T. Photographs 13 and 14 show field examples of this type. Young green stands may be up to 6 feet (2 m) high but have poor burning properties because of live vegetation.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	3.5
Dead fuel load, 1/4-inch, tons/acre	1.0
Live fuel load, foliage, tons/acre	2.0
Fuel bed depth, feet	2.0



Photo 13. Green, low shrub fields within timber stands or without overstory are typical. Example is Douglas-fir-snowberry habitat type.



Photo 14. Regeneration shrublands after fire or other disturbances have a large green fuel component, Sundance Fire, Pack River Area, Idaho.



**Fire Behavior Fuel Model 6**

Fires carry through the shrub layer where the foliage is more flammable than fuel model 5, but this requires moderate winds, greater than 8 mi/h (13 km/h) at mid-flame height. Fire will drop to the ground at low wind speeds or at openings in the stand. The shrubs are older, but not as tall as shrub types of model 4, nor do they contain as much fuel as model 4. A broad range of shrub conditions is covered by this model. Fuel situations to be considered include intermediate stands of chamise, chaparral, oak brush, low pocosin, Alaskan spruce taiga, and shrub tundra. Even hardwood slash that has cured can be considered. Pinyon-juniper shrublands may be represented but may overpredict rate of spread except at high winds, like 20 mi/h (32 km/h) at the 20-foot level.

The 1978 NFDRS fuel models F and Q are represented by this fuel model. It can be considered a second choice for models T and D and a third choice for model S. Photographs 15, 16, 17, and 18 show situations encompassed by this fuel model.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	6.0
Dead fuel load, ¼-inch, tons/acre	1.5
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	2.5



Photo 15. Pinion-juniper with sagebrush near Ely, Nev.; understory mainly sage with some grass intermixed.



Photo 16. Southern hardwood shrub with pine slash residues.

Photo 17. Low pocosin shrub field in the south.



Photo 18. Frost-killed Gambel Oak foliage, less than 4 feet in height, in Colorado.



**Fire Behavior Fuel Model 7**

Fires burn through the surface and shrub strata with equal ease and can occur at higher dead fuel moisture contents because of the flammability of live foliage and other live material. Stands of shrubs are generally between 2 and 6 feet (0.6 and 1.8 m) high. Palmetto-gallberry understory-pine overstory sites are typical and low pocosins may be represented. Black spruce-shrub combinations in Alaska may also be represented.

This fuel model correlates with 1978 NFDRS model D and can be a second choice for model Q. Photographs 19, 20, and 21 depict field situations for this model.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	4.9
Dead fuel load, 1/4-inch, tons/acre	1.1
Live fuel load, foliage, tons/acre	0.4
Fuel bed depth, feet	2.5

The shrub group of fuel models has a wide range of fire intensities and rates of spread. With winds of 5 mi/h (8 km/h), fuel moisture content of 8 percent, and a live fuel moisture content of 100 percent, the models have the values:

<b>Model</b>	<b>Rate of spread <i>Chains/hour</i></b>	<b>Flame length <i>Feet</i></b>
4	75	19
5	18	4
6	32	6
7	20	5



Photo 19. Southern rough with light to moderate palmetto understory.



Photo 20. Southern rough with moderate to heavy palmetto-gallberry and other species.



Photo 21. Slash pine with gallberry, bay, and other species of understory rough.



**Timber Group**

**Fire Behavior Fuel Model 8**

Slow-burning ground fires with low flame lengths are generally the case, although the fire may encounter an occasional “jackpot” or heavy fuel concentration that can flare up. Only under severe weather conditions involving high temperatures, low humidities, and high winds do the fuels pose fire hazards. Closed canopy stands of short-needle conifers or hardwoods that have leafed out support fire in the compact litter layer. This layer is mainly needles, leaves, and occasionally twigs because little undergrowth is present in the stand. Representative conifer types are white pine, and lodgepole pine, spruce, fir, and larch.

This model can be used for 1978 NFDRS fuel models H and R. Photographs 22, 23, and 24 illustrate the situations representative of this fuel.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	5.0
Dead fuel load, ¼-inch, tons/acre	1.5
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	0.2

Photo 22. Surface litter fuels in western hemlock stands of Oregon and Washington.



Photo 23. Understory of inland Douglas-fir has little fuel here to add to dead-down litter load.



Photo 24. Closed stand of birch-aspen with leaf litter compacted.



**Fire Behavior Fuel Model 9**

Fires run through the surface litter faster than model 8 and have longer flame height. Both long-needle conifer stands and hardwood stands, especially the oak-hickory types, are typical. Fall fires in hardwoods are predictable, but high winds will actually cause higher rates of spread than predicted because of spotting caused by rolling and blowing leaves. Closed stands of long-needled pine like ponderosa, Jeffrey, and red pines, or southern pine plantations are grouped in this model. Concentrations of dead-down woody material will contribute to possible torching out of trees, spotting, and crowning.

NFDRS fuel models E, P, and U are represented by this model. It is also a second choice for models C and S. Some of the possible field situations fitting this model are shown in photographs 25, 26, and 27.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	3.5
Dead fuel load, 1/4-inch, tons/acre	2.9
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	0.2



Photo 25. Western Oregon white oak fall litter; wind tumbled leaves may cause short-range spotting that may increase ROS above the predicted value.



Photo 26. Loose hardwood litter under stands of oak, hickory, maple and other hardwood species of the East.



Photo 27. Long-needle forest floor litter in ponderosa pine stand near Alberton, Mont.



**Fire Behavior Fuel Model 10**

The fires burn in the surface and ground fuels with greater fire intensity than the other timber litter models. Dead-down fuels include greater quantities of 3-inch (7.6-cm) or larger limbwood resulting from overmaturity or natural events that create a large load of dead material on the forest floor. Crowning out, spotting, and torching of individual trees are more frequent in this fuel situation, leading to potential fire control difficulties. Any forest type may be considered if heavy down material is present; examples are insect- or disease-ridden stands, wind-thrown stands, overmature situations with deadfall, and aged light thinning or partial-cut slash.

The 1978 NFDRS fuel model G is represented and is depicted in photographs 28, 29, and 30.

The fire intensities and spread rates of these timber litter fuel models are indicated by the following values when the dead fuel moisture content is 8 percent, live fuel moisture is 100 percent, and the effective windspeed at midflame height is 5 mi/h (8 km/h):

Model	Rate of spread <i>Chains/hour</i>	Flame length <i>Feet</i>
8	1.6	1.0
9	7.5	2.6
10	7.9	4.8

Fires such as above in model 10 are at the upper limit of control by direct attack. More wind or drier conditions could lead to an escaped fire.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	12.0
Dead fuel load, 1/4-inch, tons/acre	3.0
Live fuel load, foliage, tons/acre	2.0
Fuel bed depth, feet	1.0

Photo 28. Old-growth Douglas-fir with heavy ground fuels.



Photo 29. Mixed conifer stand with dead-down woody fuels.



Photo 30. Spruce habitat type where succession or natural disturbance can produce a heavy downed fuel load.



# 146 Logging Slash Group

## Fire Behavior Fuel Model 11

Fires are fairly active in the slash and herbaceous material intermixed with the slash. The spacing of the rather light fuel load, shading from overstory, or the aging of the fine fuels can contribute to limiting the fire potential. Light partial cuts or thinning operations in mixed conifer stands, hardwood stands, and southern pine harvests are considered. Clearcut operations generally produce more slash than represented here. The less-than-3-inch (7.6-cm) material load is less than 12 tons per acre (5.4 t/ha). The greater-than-3-inch (7.6-cm) is represented by not more than 10 pieces, 4 inches (10.2 cm) in diameter, along a 50-foot (15-m) transect.

The 1978 NFDRS fuel model K is represented by this model and field examples are shown in photographs 31, 32, and 33.

### Fuel model values for estimating fire behavior

Total fuel load, < 3-inch dead and live, tons/acre	11.5
Dead fuel load, 1/4-inch, tons/acre	1.5
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	1.0



Photo 31. Slash residues left after sky-line logging in western Montana.



Photo 32. Mixed conifer partial cut slash residues may be similar to closed timber with down woody fuels.



Photo 33. Light logging residues with patchy distribution seldom can develop high intensities.



**Fire Behavior Fuel Model 12**

Rapidly spreading fires with high intensities capable of generating firebrands can occur. When fire starts, it is generally sustained until a fuel break or change in fuels is encountered. The visual impression is dominated by slash and much of it is less than 3 inches (7.6 cm) in diameter. The fuels total less than 35 tons per acre (15.6 t/ha) and seem well distributed. Heavily thinned conifer stands, clearcuts, and medium or heavy partial cuts are represented. The material larger than 3 inches (7.6 cm) is represented by encountering 11 pieces, 6 inches (15.2 cm) in diameter, along a 50-foot (15-m) transect.

This model depicts 1978 NFDRS model J and may overrate slash areas when the needles have dropped and the limbwood has settled. However, in areas where limbwood breakup and general weathering have started, the fire potential can increase. Field situations are presented in photographs 34, 35, and 36.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	34.6
Dead fuel load, 1/4-inch, tons/acre	4.0
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	2.3

Photo 34. Ponderosa pine clearcut east of Cascade mountain range in Oregon and Washington.



Photo 35. Cedar-hemlock partial cut in northern Idaho, Region 1, USFS.



Photo 36. Lodgepole pine thinning slash on Lewis and Clark National Forest. Red slash condition increases classification from light to medium.



**Fire Behavior Fuel Model 13**

Fire is generally carried across the area by a continuous layer of slash. Large quantities of material larger than 3 inches (7.6 cm) are present. Fires spread quickly through the fine fuels and intensity builds up more slowly as the large fuels start burning. Active flaming is sustained for long periods and a wide variety of firebrands can be generated. These contribute to spotting problems as the weather conditions become more severe. Clear-cuts and heavy partial-cuts in mature and overmature stands are depicted where the slash load is dominated by the greater-than-3-inch (7.6-cm) diameter material. The total load may exceed 200 tons per acre (89.2 t/ha) but fuel less than 3 inches (7.6-cm) is generally only 10 percent of the total load. Situations where the slash still has "red" needles attached but the total load is lighter, more like model 12, can be represented because of the earlier high intensity and quicker area involvement.

The 1978 NFDRS fuel model I is represented and is illustrated in photographs 37 and 38. Areas most commonly fitting this model are old-growth stands west of the Cascade and Sierra Nevada Mountains. More efficient utilization standards are decreasing the amount of large material left in the field.

**Fuel model values for estimating fire behavior**

Total fuel load, < 3-inch dead and live, tons/acre	58.1
Dead fuel load, 1/4-inch, tons/acre	7.0
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	3.0

For other slash situations:

- Hardwood slash ..... Model 6
- Heavy "red" slash ..... Model 4
- Overgrown slash ..... Model 10
- Southern pine clearcut slash ..... Model 12

The comparative rates of spread and flame lengths for the slash models at 8 percent dead fuel moisture content and a 5 mi/h (8 km/h) midflame wind are:

<b>Model</b>	<b>Rate of spread</b> <i>Chains/hour</i>	<b>Flame length</b> <i>Feet</i>
11	6.0	3.5
12	13.0	8.0
13	13.5	10.5



Photo 37. West coast Douglas-fir clear-cut, quality of cull high.



Photo 38. High productivity of cedar-fir stand can result in large quantities of slash with high fire potential.

## CORRELATION OF FIRE BEHAVIOR FUEL MODELS AND NFDRS FUEL MODELS

The following section, which correlates fuel models used for fire behavior with those used for fire danger rating, should help fire behavior officers (FBO's), researchers, or other concerned personnel understand the relationship of the two sets of fuel models. For initial fire behavior estimates, the fuel model used for fire danger rating can be cross referenced to a fire behavior fuel model suitable for the general area of interest. It also provides useful background about the character of each fuel model so specific selections can be made where vegetation varies considerably. Combining this information with the photographic representations of each of the 13 fuel models presents the concept that a single fuel model may represent several vegetative groups. **It is important that one maintain an open, flexible impression of fuel models so as to recognize those vegetative groups with common fire-carrying characteristics.**

The correlation with the 1978 NFDRS fuel models allows conversion from fire danger trend measurements to field-oriented prediction of fire behavior. The great variety of fuel, weather, and site conditions that exist in the field means the user of fuel models and fire behavior interpretation methods must make observations and adjust his predictions accordingly. Calibration of the fire behavior outputs for the selected fuel model can allow more precise estimation of actual conditions. This has been practiced in the field by instructors and trainees of the Fire Behavior Officer's (FBO) School, S-590, and has provided a greater degree of flexibility in application.

The fuel models shown in figure 3 were aligned according to the fuel layer controlling the rate of fire spread. Some second and third choices are indicated for situations where fire spread may be governed by two or more fuel layers, depending on distribution and moisture content. From the four climates used in the 1978 NFDRS,

climate 3 was used, with the live herbaceous fuels 99.7 percent cured and a wind of 20 mi/h (32 km/h) at the 20-foot (6.1-





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### Introduction

More than 64 years ago, foresters in the United States were concerned about fire danger and were attempting to develop methods to assess the hazard (Dubois 1914). The “inflammability” of a situation depended on four elements: (1) amount of ground fuels; (2) ease of ignition; (3) dryness of the cover; and (4) slope. Three fuel types were considered: grass, brush, and timber. In 1978, we are still concerned about fire danger and fire behavior. Through the use of mathematical fire behavior models (Rothermel 1972) and fire danger ratings (Deeming and others 1977), we can evaluate how fire danger changes with weather, fuels, and slope. In addition, the fire behavior officer on a fire can estimate the fire behavior for the next burning period if he can define the fuels (Albini 1976). Dubois grouped fuels as grass, brush, and timber, and these general groupings are still used with the addition of slash. Several fuel types or fuel models are recognized within each group. For fire danger rating, we have gone from two fuel models (USDA Forest Service 1964) to nine in 1972 (Deeming and others 1972) and 20 in 1978 (Deeming and others 1977). Research efforts to assist the fire behavior officer have utilized the 13 fuel models tabulated by Rothermel (1972) and Albini (1976).

### Fuels Defined

Fuels are made up of the various components of vegetation, live and dead, that occur on a site. The type and quantity will depend upon the soil, climate, geographic features, and the fire history of the site. To a large extent, potential evapotranspiration and annual precipitation combinations with altitude and latitude changes can describe the expected vegetation and have been used for vegetation maps (Küchler 1967). An adequate description of the fuels on a site requires identifying the fuel components that may exist. These components include the litter and duff layers, the dead-down woody material, grasses and forbs, shrubs, regeneration and timber. Various combinations of these components define the major fuel groups of grass, shrub, timber and slash. Certain features of each fuel component or the lack of it contributes to the description of the fuels in terms suitable to define a fuel model. For each fuel component certain characteristics must be quantified and evaluated to select a fuel model for estimating fire behavior. The most important characteristics for each component are:

1. Fuel loading by size classes
2. Mean size and shape of each size class
3. Compactness or bulk density
4. Horizontal continuity
5. Vertical arrangement
6. Moisture content
7. Chemical content, ash, and volatiles.

Each of the above characteristics contributes to one or more fire behavior properties. Fuel loading, size class distribution of the load, and its arrangement (compactness or bulk density) govern whether an ignition will result in a sustaining fire. Horizontal continuity influences whether a fire will spread or not and how steady

rate of spread will be. Loading and its vertical arrangement will influence flame size and the ability of a fire to “torch out” the overstory. With the proper horizontal continuity in the overstory, the fire may develop into a crown fire. Low fuel moisture content has a significant impact upon fire behavior affecting ignition, spread, and intensity; with high winds it can lead to extreme fire behavior. Certain elements of the fuel’s chemical content, such as volatile oils and waxes, aid fire spread, even when moisture contents are high. Others, like mineral content, may reduce intensity when moisture contents are low. High fuel loads in the fine fuel size classes with low fuel moisture contents and high volatile oil contents will contribute to rapid rates of spread and high fire line intensities, making initial attack and suppression difficult.

### How Fuels Have Been Described

In the expression of fire danger presented by Dubois (1914), the fuel types of grass, brush, and timber were defined, utilizing three causes—amount of fuel on the ground, lack of moisture in the cover, and slope—and two effects—ease of ignition and rate of fire growth or spread. As Dubois pointed out, however, not enough study had been made of rate of spread to effectively describe differences among the fuel types. Sparhawk (1925) conducted an extensive study of fire size as a function of elapsed time from discovery to initial attack by broad forest cover types. Twenty-one fire regions for the western United States and the Lake States were defined and up to seven forest types selected for each region. These forest types basically were grass, brush, timber, and slash descriptions. The ranking of area growth rates by type showed the highest growth rates occurred in grasses and brush types, followed by slash and open timber situations and concluding with low growth rates in closed timber types. Sparhawk made the following comment regarding his data:

Rating obtained, therefore, will represent averages of fairly broad application, but may now show what can be expected on individual units. These factors can be allowed for only when the fire records and the inventory of our forest resources include information concerning them.

Show and Kotok (1929) reported on a preliminary study of forest cover as related to fire control. Study of the nine major cover types in northern California showed definite differences between them regarding fire danger, ignition risk, rate of spread, and type of fire and several other fire control subjects. They did not attempt to complete analysis proposed by Sparhawk because the variability of individual fires was so great and the classification of type and hazard classes was so incomplete. However, their nine cover types fit a broader classification of:

1. Woodlands and grasslands
2. Chaparral and brush fields
3. Timber cover types:
  - a. western yellow pine and mixed conifer
  - b. Douglas-fir
  - c. sugar pine-fir and fir.



These cover types and their classification express the broad groupings of grass-dominated, brush-dominated, and timber-residue-dominated fuel groups. Timber residues can be either naturally occurring dead woody or activity-caused slash. In terms of fire behavior, these cover types could be characterized as follows:

Crown fires (occur in secondary or primary overstory)—chaparral and brush types.

Surface fires (occurs in surface litter, dead down woody, and herbaceous material)—woodlands and grasslands; western yellow pine and mixed conifer; Douglas-fir.

Ground fires (occur in litter, duff, and subsurface organic material) sugar pine-fir; fir type.

This work showed the complexity of establishing hour control needs and contributes to continued efforts to describe types in terms of fire growth and control difficulty.

Hornby (1935) developed a fuel classification system that formalized the description of rate of spread and resistance to control into classes of low, medium, high, and extreme. For the Northern Rocky Mountains, the standard timber types relative ranking was similar to that of Show and Kotok as well as work in Colorado by Bates (1923) and described by Hornby (1935):

1. Brush—grass
2. Ponderosa pine
3. Larch—fir
4. Douglas-fir and lodgepole pine
5. White pine and lodgepole pine
6. Subalpine fir
7. White fir and spruce.

Classification of these fuels was accomplished by utilizing 90 men experienced in fire hazard. A total of 42 ratings were assigned to typical fuels in Region 1. Hornby noted that a weakness of the system was the use of estimates rather than extensive accurate measurements, but until enough years of data had been collected on contributing influences, some procedures for rating fuels were needed. Adaptations of Hornby's approach have been utilized in the eastern United States (Jemison and Keetch 1942) and modified later in the West (Barrows 1951). Most Forest Service regions utilized some version of the Hornby rating method but generally assigned rate of spread values unique to their area, thereby reducing comparability. This is illustrated by a sampling of the number of ratings used by various regions and some of the variation that existed for rate of spread (ROS) classes.

Region	Year	No. of ratings	ROS (chains/hour)
Region 1	1969	234	High (51)
Region 1	1974	4	High (25)
Region 2	1972	59	High (25)
Region 3	1970	11	
Region 4	1972	48	High (30)
Eastern	1966	15	
Region 5	1973	17	
Region 6	1972	16	High (25)
		examples	
Region 8	1975		High (>10)
Region 9	1970	10	

The variation of ROS rating is due not so much to fuels alone as to the combination of fuels, climate, season, and local weather. These additional factors influence the quantity of live fuel and the moisture content of the dead fuels. Other agencies such as the BLM have utilized the approach for each management area and have a set of ratings for six areas.

Fuels became a consideration in fire danger ratings in the 1950's; in 1958 an effort was made to unify the eight fire danger rating systems into one national system (Deeming and others 1972). Two fuel conditions were considered—fuels sheltered under a timber cover and fuels in an open, exposed site. A relative spread index was developed and brought into general use by 1965. Review of the approach and the expressed need for the ignition, risk, and energy indexes resulted in a research effort that yielded the 1972 National Fire Danger Rating System (NFDRS). Fuels could be considered in greater detail because a mathematical fire spread model had been developed by Rothermel (1972). Nine specific descriptions of fuel properties, called fuel models, were developed for the NFDRS (Deeming and Brown 1975). Fahnestock (1970), in his guide "Two keys for appraising forest fire fuels," was among the first to use the Rothermel fire spread model. The keys provide tools for recognizing the differences in fuel types and identifying the relative fire hazard potential in terms of rate of spread or crowning. To use the keys, one must describe physical fuel properties in Fahnestock's terms: fine, small, medium for size classes and sparse, open, dense, fluffy, or thatched for compactness or combination of loading and depth. By keying on the fuel properties of the site, one of the 36 rate-of-spread ratings or one of the 24 crowning-potential ratings can be selected.

Fahnestock interpreted the size class descriptions for each fuel stratum according to the physical dimensions and timelags associated with the 1964 NFDRS. Timelag is the time necessary for a fuel size class to change 63 percent of the total expected change. These same descriptions were used when fuel models were developed to represent broad vegetative types of grasslands, brush-fields, timbered land, and slash. Within each fuel model, the load was distributed by size or timelag classes, correlated with groupings of foliage and twigs, branchwood, and tree or shrub material as follows:

Size, diameter <i>Inch</i>	Timelag <i>Hours</i>
< 1/4	1
1/4 to 1	10
1 to 3	100
> 3	1,000 <sup>1</sup>

<sup>1</sup>Large fuels or layers slow to respond are recognized in the fuel models available in the 1978 NFDRS.

The initial fuel models were documented by Rothermel (1972) and these 13 models were reduced to 9 models for the 1972 NFDRS (Deeming and others 1972). The original 9 fuel models, except for one, have been retained in the 1978 NFDRS and supplemented by 11 others to accom-

moderate differences across the country. For fire behavior officer training, the 13 fuel models initially presented by Rothermel (1972) and Albini (1976) are currently being used. The 13 models encompass those of the 1972 NFDRS and can be correlated to the 1978 NFDRS models. At the present time, the fuel models have the broadest application, while other research is providing fuel models for specific applications (Kessell 1976, 1977; Bevins 1976; Kessell, Cattelino, and Potter 1977; Philpot 1977; Hough and Albini 1978; Rothermel and Philpot 1973).

Anderson, Hal E.

1982. Aids to determining fuel models for estimating fire behavior. USDA For. Serv. Gen. Tech. Rep. INT-122, 22p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Presents photographs of wildland vegetation appropriate for the 13 fuel models used in mathematical models of fire behavior. Fuel model descriptions include fire behavior associated with each fuel and its physical characteristics. A similarity chart cross-references the 13 fire behavior fuel models to the 20 fuel models used in the National Fire Danger Rating System.

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Keywords: forest fuels, modeling, fire behavior

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# BUSH-CONTROL STUDIES IN THE DRIER AREAS OF KENYA

## IV. EFFECTS OF CONTROLLED BURNING ON SECONDARY THICKET IN UPLAND *ACACIA* WOODLAND

BY D. B. THOMAS\* AND D. J. PRATT

*Ministry of Agriculture and Animal Husbandry,  
P.O. Box 30028, Nairobi, Kenya*

It is generally recognized that fire is one of the most potent of the extraneous environmental factors which shape and change biological communities (Bartlett 1955, 1957, 1961; West 1965). However, much still remains to be learned of its exact effects and its usefulness in land-management. In the field of bush-control, certainly, there is a practical need for such knowledge, for, over much of pastoral Africa, controlled burning represents the best hope at present for the economic control of woody species.

Previous papers in this series have included some data on the effects of fire, but the present paper is the first to deal exclusively with the effects of controlled burning regimes. It presents the results of a trial undertaken in Machakos District, Kenya, to determine the susceptibility to fire of the secondary thicket species which commonly occur locally in upland *Acacia* woodland.

### EXPERIMENTAL DETAILS

#### *Site*

The site chosen was an area of dense secondary bushland on Katumani Experimental Farm, Machakos, on land sloping (at 1:6) towards the Potha River, at longitude 37° 15' E and latitude 1° 34' S. The altitude is 5200 ft (1580 m) and the average annual rainfall is approximately 25 in. (635 mm), distributed in two seasons (see Table 1). The soil is a reddish sandy loam, shallow in places, derived *in situ* from basement complex gneisses.

The natural vegetation is a form of upland *Acacia* woodland (Trapnell & Griffiths 1960), with many species, including †*A. gerrardii* var. *latisiliqua*, *A. nilotica* subsp. *subalata*, *A. tortilis* subsp. *spirocarpa*, *Albizia amara* subsp. *sericocephala*, *Combretum molle*, *Commiphora africana*, *Dombeya rotundifolia*, *Grewia tembensis*, *Lannea floccosa* and *Terminalia brownii*.

The main components of the thickets which had invaded the woodland were *Acacia brevispica*, *Acalypha fruticosa* Forsk., *Aspilia* sp., *Crotalaria saxatilis* and *Maytenus putterlickioides*. All are multi-stemmed species, which grow to a height of more than 6 ft. *Acacia brevispica* and *Maytenus putterlickioides*, which have spines or prickles and often exceed 12 ft in height, are the most undesirable species, but the others, especially the *Aspilia*, are efficient colonizers and often dominate the association.

Although this thicket association occurs mainly in Machakos District, the species have a wide range. *Acalypha fruticosa* occurs in several *Acacia* and *Commiphora*

\* Present address: P.O. Box 56, Njoro, Kenya.

† Except where an authority is given, all plant names follow Dale & Greenway (1961) or Bogdan (1958).

158 associations from the coast hinterland to western Kenya and often dominates the understorey in mixed *Acacia* bushland; *Maytenus putterlickioides* is particularly troublesome in *Acacia-Commiphora* bushland of eastern Kenya; *Aspilia* invades many disturbed communities throughout the country; and *Acacia brevispica* is widespread but it is most troublesome in upland *Acacia* woodland (see Pratt 1966).

The site had not been grazed for some time and there was a well-developed cover of perennial grass between the thickets. The dominant species were *Digitaria milanjana*, *D. scalarum*, *Eustachys paspaloides*, *Heteropogon contortus*, *Panicum maximum* and *Themeda triandra*, plus a complement of annual species.

#### Treatments

Three plots of approximately 2 ac (0.81 ha) each were laid out. One plot was burned in 3 successive years (1958, 1959 and 1960), one was burned twice (1958 and 1960) and the remaining plot was not burned. Half of each plot was slashed at the start of the experiment. There was no replication.

Burning was carried out on 16 October 1958, 24 October 1959 and 11 October 1960. In 1958 and 1959, an area-ignition method was used, in which a line of men moved rapidly through each plot from the down-wind side firing it in as many places as possible. The 1959 fire was not very successful. In 1960, the plots were ringburnt, starting on the down-wind edge and moving around the perimeter to finish on the up-wind boundary. Maize cobs, soaked in paraffin and attached to wire handles, were used to light the fires.

In the slashed areas, all woody plants except the larger trees were cut to ground level by machet in August 1958, 2 months before the first burn. All cut material was left where it lay.

The site was not grazed during the experimental period except when cattle and small stock gained access from the Kamba Native Land Unit. The site was attractive also to the stock-owners as a source of firewood.

#### Records

This was essentially a preliminary observational trial, supported by photographic records. Some quantitative data were collected, however, on the effect of fire on the five thicket species listed above, and on the grass cover.

In the unslashed areas of the plots burnt twice and thrice, a number of individual plants (generally ten) of each of the thicket species were selected and classified according to height and stem number. All detailed observations on the effects of fire were confined to these individuals, except in the case of *Aspilia*, where counts of dead and live plants, including seedlings, were made within two 30 × 6 ft permanent quadrats per plot. Recordings were made after each burn.

Individual plants were located by their direction and distance from permanent, numbered concrete beacons which were placed in each plot. The best type of block was rectangular, 5 in. in cross-section and 12 in. long, with a hole in the centre of the top into which a peg could be inserted (fixed pegs made the blocks too easy for trespassers to remove). When a block was in position, about 1 in. projected above ground. Each beacon had a groove on the top surface running from the centre hole to one corner. When records were made, a peg was placed in the hole and over this was placed a hard-board disc, 18 in. across, marked with lines 5° apart and numbered 1–72. The disc was

then orientated so that line 1 coincided with the groove in the beacon and the selected plants were located by the relevant line number and the distance measured by survey chain.

The basal cover of grass was measured in 1959 and 1960 on the slashed areas of the burnt plots using the Tidmarsh wheel method (Tidmarsh & Havenga 1955). The wheel was pulled across each plot on roughly equidistant lines and two sets of data, each comprising over 1000 points, were collected at each recording. The Tidmarsh wheel, which was designed for use in arid vegetation, was not well suited to the conditions of the present study.

Fire temperatures and supporting meteorological data were not recorded. The quantity of combustible material was measured by quadrat cuts before the final burn. Rainfall data from the farm meteorological station were taken to relate adequately to the experimental site (see Table 1).

Table 1. *Rainfall data (in.)*

Month	Potha* (40-year average)	Katumani Experimental Farm		
		1958	1959	1960
January	1.24	0.90	1.42	0.21
February	1.60	6.56	0.71	0.69
March	3.41	4.27	5.51	4.32
April	6.24	7.56	3.18	5.94
May	2.21	4.50	4.40	1.17
June	0.32	1.00	nil	0.02
July	0.10	0.47	0.01	0.96
August	0.09	nil	0.16	nil
September	0.46	0.06	0.06	0.05
October	1.34	0.33	nil	2.53
November	4.28	4.31	6.23	1.06
December	3.25	2.58	1.81	6.44
Total	24.54	32.54	23.49	23.39

\* The Potha and Katumani recording stations are at the same altitude and just over 2 miles apart: consequently the average annual rainfall of Katumani, when the farm was first established, was taken to be about 25 in. This figure is quoted in the text, but if the mean of the differences in annual rainfall between the two stations for the 8 years 1957-64 is applied as a correction factor to the long-term average for Potha, the mean annual rainfall of Katumani is estimated as 29.5 in. and the gradient between the two stations is 0.5 in. per 400 yd (10 mm per 280 m).

## RESULTS

### *General effects of fire and slashing*

Plate 10 shows that repeated burning had a most profound effect on the Katumani thicket association, even without preliminary slashing.

The 1958 fire was very hot. Where it passed, it killed the aerial parts of most of the plants up to about 12 ft, though it had little effect on the population of established plants. Its passage was facilitated by the preliminary slashing treatment and it consumed most of the tangled mass of debris left by slashing. Without slashing, it failed to penetrate many of the denser thickets (Phot. 1).

Table 2. *Effect of fire on selected individuals of five thicket species (unslashed plots only)*

Original height (in.)	Original no. of live stems	After first burn* Regeneration‡	No. of live stems	After last burn† Regeneration‡	No. of live stems
<b>I. <i>Acacia brevispica</i></b>					
<b>(a) Burnt thrice (1958, 1959, 1960)</b>					
144	9	B	8	B	20
120	27	B	num.	B	27
120	15	B	22	B	22
120	10	B	12	B	4
120	22	B	20	B	12
108	11	B	12	B	num.
79	12	B	21	B	16
72	7	B	8	B	14
70	32	B	25	B	num.
63	2	B	3	B	7
<b>(b) Burnt twice (1958, 1960)</b>					
84		BT	4	T	?
84		BT	6	B	2
72		BT	12	T	?
72		BT	12	T	?
66		B	7	B	15
60		BT	11	T	10
36		B	1	B	10
24		B	3	nil	nil
24		B	2	B	1
18		B	2	Not relocated	
18		B	6	T	6
<b>II. <i>Maytenus putterlickioides</i></b>					
<b>(a) Burnt thrice (1958, 1959, 1960)</b>					
120	15	B	20	nil	nil
108	7	B	12	nil	nil
108	8	B	40	B	24
96	9	B	23	B	27
96	10	B	28	nil	nil
96	13	B	num.	B	16
84	6	B	34	B	16
72	16	B	34	B	14
66	25	B	num.	B	3
?	?	BT	20	B	8
<b>(b) Burnt twice (1958, 1960)</b>					
96	1	B	num.	nil	nil
96	13	B	?	nil	nil
96	7	B	num.	B	num.
84	12	B	num.	B	30
60	?	BT	13	T	?
36	2	B	7	B	7
<b>III. <i>Acalypha fruticosa</i></b>					
<b>(a) Burnt thrice (1958, 1959, 1960)</b>					
78	17	B	num.	nil	nil
72	12	B	num.	B	13
72	37	B	num.	nil	nil
67	34	B	num.	nil	nil
66	num.	B	num.	nil	nil
66	25	B	num.	nil	nil
63	40	B	num.	nil	nil
60	21	B	num.	nil	nil
60	19	B	num.	nil	nil
60	num.	B	num.	B	2
54	36	B	num.	nil	nil



Table 2 (continued)

Original height (in.)	Original no. of live stems	After first burn* Regeneration†	No. of live stems	After last burn† Regeneration‡	No. of live stems
(b) Burnt twice (1958, 1960)					
72	num.	B	num.	B	7
60	num.	B	num.	B	4
60	num.	B	num.	B	37
60	num.	B	num.	nil	nil
48	num.	B	num.	nil	nil
48	num.	B	num.	Not relocated	
48	num.	B	num.	nil	nil
48	num.	B	num.	nil	nil
48	num.	B	num.	nil	nil
36	num.	B	num.	B	4
IV. <i>Crotalaria saxatilis</i>					
(a) Burnt thrice (1958, 1959, 1960)					
84	7	B	num.	nil	nil
72	14	B	num.	nil	nil
72	8	B	num.	nil	nil
48	6	B	num.	B	25
48	3	B	num.	B	13
48	4	B	num.	Not relocated	
36	15	B	num.	nil	nil
36	4	B	num.	Not relocated	
30	5	B	num.	nil	nil
24	4	B	num.	Not relocated	
(b) Burnt twice (1958, 1960)					
96	8	B	num.	B	num.
76	5	B	num.	B	num.
36	num.	B	num.	B	10
36	6	B	num.	B	num.
36	8	B	num.	B	num.
36	4	B	num.	B	num.
?	?	B	num.	T	?
?	?	B	num.	BT	num.
?	?	B	num.	B	7
?	?	B	4	nil	nil
V. <i>Aspilia</i> sp.					
(a) Burnt thrice (1958, 1959, 1960)					
72	17	B	16	nil	nil
72	19	B	8	nil	nil
54	13	B	13	B	3
54	10	B	10	B	8
54	14	B	23	B	42
48	3	B	4	B	8
48	23	B	30	nil	nil
48	9	B	28	B	10
42	25	B	14	nil	nil
36	11	B	11	B	29
24	7	B	18	Not relocated	
(b) Burnt twice (1958, 1960)					
60	4	B	5	B	12
48	1	B	4	B	7
36	3	B	10	B	28
36	3	B	4	B	5
36	4	B	8	B	25
36	3	B	4	B	5
36	1	B	7	B	13
24	3	B	4	B	3
18	?	B	12	B	15
18	?	B	3	B	7

\* Recorded 15 August 1959 (three burns treatment), 2 August 1960 (two burns treatment).

† Recorded 25 November 1960.

‡ Regeneration from base (B), top (T), or both (BT); 'nil' indicates a dead plant; num. (= numerous) indicates more than forty stems.

Where individuals were 'not relocated', it is most probable that they were in fact killed.

The 1959 fire, applied to one plot only, was less satisfactory (due partly to relatively light rain and illegal grazing which decreased the amount of grass), but the final fire (1960) was again very hot and consumed much of the top-growth that had been killed previously. It also decreased considerably the population of woody plants (Phot. 2). Herbage samples were taken from the slashed areas before the final burn in 1960. The plot which had previously been burnt once only (in 1958), carried 3200 lb of combustible material per acre, 760 lb more than the plot that had been burnt in both 1958 and 1959.

After the final burn, the slashed parts of the two burnt plots looked very similar, but in the unslashed parts the third fire had been necessary to complete the opening-up of all the thicket patches (Photos. 1 and 2). With only two burns, some thickets remained unburnt. No immediate difference in the numbers of dead bushes was observed between the slashed and unslashed areas of the burnt plots, but subsequently, when the thicket began to encroach again, there was clearly less *Aspilia* (the main invader) on the areas which had been slashed.

Burning damaged the larger trees present relatively little. In the absence of fire, slashing only temporarily decreased the thicket canopy, and cut stems regenerated rapidly.

#### *Effects of fire on individual bushes*

Table 2 shows the fate of the individual bushes studied.

##### *Acacia brevispica*

The first burn killed the top growth of all the twenty-one bushes studied except for five which were growing together in a thicket where there was insufficient grass to carry the fire. All the burnt bushes regenerated from the crown, at an average rate of 4–6 ft in 1 year. The average increase in the number of stems was 20%.

Subsequent fires killed no more bushes and did not control the increase in numbers of stems. Only one bush was recorded as dead (on the plot burnt twice). The stems killed in the first burn were not readily set on fire in subsequent burns and many were still present in 1961.

##### *Maytenus putterlickioides*

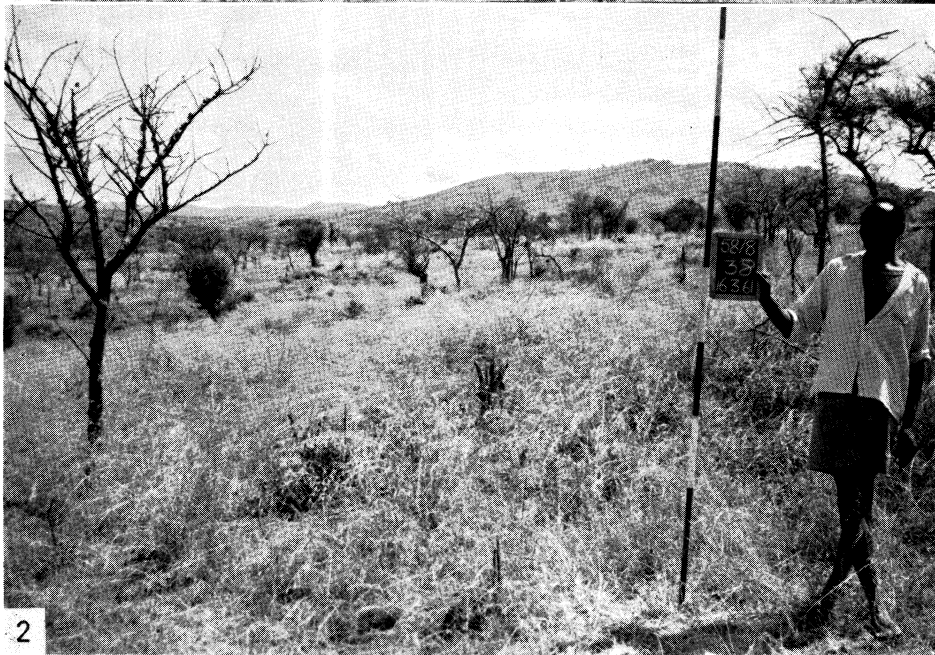
The first fire affected *Maytenus* in much the same way as *Acacia brevispica*, but the new shoots grew about 2 ft only in the year following the first burn, while the number of stems increased by over 150%.

There was no appreciable difference between burning twice and thrice. Under both treatments, about one-third of the bushes were killed. As with *A. brevispica*, the stems killed in the first burn did not ignite readily in subsequent burns.

##### *Acalypha fruticosa*

As with *Maytenus*, the first fire killed no plants, and regeneration from the base of the plants was prolific, though it was slightly slower than in *Maytenus*.

Unlike *Acacia brevispica* and *Maytenus*, many of the *Acalypha* plants were killed by later fires—over 80% when three burns were applied and about 60% with two burns. Most of the stems killed by the first fire caught fire in 1960, so that new regeneration was exposed to high temperatures. As this species was one of the main components of the thicket patches, the density of the thicket was decreased markedly under both burning treatments.



PHOT. 1. A thicket patch in the unslashed area of the plot burnt 3 years in succession, photographed in October 1959, shortly before the second burn. The first burn had affected the edges of the thicket only. The main constituents of the thicket are *Aspilia* and *Acalypha fruticosa* (the bush in the centre foreground), with *Rhus ?vulgaris*, *Grewia* sp., *Crotalaria saxatilis*, *Cordia* sp. and *Asparagus* sp.

PHOT. 2. The same site photographed in March 1961, after the third burn. The whole thicket has been burned to the ground and many plants (including the *Acalypha* in the centre foreground) killed outright. The tree on the left (*Lannea floccosa*) suffered no permanent damage. The grass cover is dominated by *Themeda triandra*.

(Facing p. 330)

*Crotalaria saxatilis*

All bushes regenerated after the first burn, and the number of stems increased more than five-fold. Regeneration was slow, however, and mean stem height was only 1 ft 1 year later. Three burns, which killed 70–80% of the plants, were noticeably more effective than two burns, which killed only 10%.

*Aspilia* sp.

The first burn killed the aerial parts of all bushes, but regeneration reached 2–3 ft in height in the following year. The increase in stem number was small. Three burns killed 40–50% of the plants, whereas two burns not only killed none, but increased the stem number even more. The dead stems did not burn as readily as those of *Acalypha*.

For this species, supplementary data are available on the effect of fire on random populations within permanent quadrats. Table 3 shows that fire had a profound effect on a complete population, when about half the total were under 1 ft in height. One burn killed about half the total population; two or three burns killed about 80%.

Table 3. *Effect of fire on a complete population of Aspilia (No. per 360 ft<sup>2</sup>)*

Treatment	After first burn (11 August 1959)		After last burn (25 November 1960)	
	Total*	No. alive	No. alive	Total kill
Burnt thrice (1958, 1959 and 1960)	230	119	37	83.9%
Burnt twice (1958 and 1960)	149	73	26	82.6%

\* The total (alive plus dead) is taken as equal to the number alive before the treatments were applied.

Table 4. *Effect of burning on percentage basal cover (slashed plots only)*

Treatment	After first burn (31 August 1959)	After last burn (2 December 1960)
Burnt thrice (1958, 1959 and 1960)	21.1	12.1
Burnt twice (1958 and 1960)	25.0	15.8

*Effects of fire on grass cover*

The Tidmarsh wheel data (Table 4) confirm the visual impression that burning decreased basal cover. The confidence limits given by Tidmarsh & Havenga (1955) show that the decreases were significant at  $P < 1\%$  under both treatments. Quantitative data on species composition were not obtained, but *Heteropogon contortus* and *Themeda triandra* seemed to increase on the burnt plots during the course of the trial, while there was a noticeable increase of *Panicum maximum* in burned thickets.

## DISCUSSION

The trial was informative at two levels. It showed that fire can be a practical method of clearing the secondary thicket studied, and it also yielded useful data on the relative susceptibility of species to fire and on some of the factors which control fire susceptibility. The latter aspects are given precedence here.

*Definition of fire susceptibility*

In the absence of an accepted series of standard terms to describe the relative susceptibility of plants to fire, the tendency is to use arbitrary and undefined terms with no quantitative basis. Also, although it is known that the response of plants to fire depends on the character, frequency and number of fires applied (see West 1965), such terms are often used with little or no indication of the conditions under which they apply.

With the present data, it is impossible to describe the relative susceptibility of the species studied unless a series of terms is first defined and unless the terms are then qualified, whenever used, by reference to an exact burning regime.

The terms chosen follow Trapnell (1959)—except that *fire-sensitive*\* is preferred to *fire-tender*—equating them to percentage mortality as follows:

	% kill
Tolerant*	< 10
Semi-tolerant	10–39
Sensitive	40–70
Intolerant	> 70

On this basis, and on the evidence of the individual bushes (Table 2), all of the species studied tolerated a single fire. *Acacia brevispica* tolerated three annual burns, but was only semi-tolerant when burnt twice (in 1958 and 1960); whereas *Aspilia* tolerated the latter treatment but was sensitive to the former. With both these species, tolerance was shown not only by absence of dead plants but by a continuing increase in stem number. *Maytenus putterlickioides* was semi-tolerant of both treatments; while *Acalypha fruticosa* and *Crotalaria saxatilis* were intolerant of three annual burns, but varied in their reaction to two burns, *Acalypha* being sensitive and *Crotalaria* tolerant. (The one *Crotalaria* plant killed was an atypical specimen which was almost killed by the first fire—see Table 2.)

With respect to those species which were affected differently by two and three burns, it is not clear whether the difference was associated with the number or the frequency of the fires applied. A comparison of the effects of burning in 1958 and 1960 (the two burns treatment) with the effects of burning in 1958 and 1959 (the first stage of the three burns treatment) should have thrown light on this point, but the 1959 burn was not effective enough for meaningful comparisons. However, the killing of *Aspilia* by three successive burns was almost certainly due more to the frequency than to the number of fires, for the two burns treatment, far from killing the plants, increased the number of stems in 90% of the plants studied. Also, where a species is damaged more by two burns applied on a biennial pattern than by three successive burns, as appears true of *Acacia brevispica*, only frequency can be involved.

Of the final definitions of the nature of fire susceptibility in the species studied, the most exact is that for *Aspilia*. In full, this is: that, under a burning regime extending over 3 years and with all burns applied at the end of the dry-season, mature plants of *Aspilia* are sensitive to annual burning but tolerant of less frequent burning, while seedling plants are intolerant of even one fire. In this form, the definition of the susceptibility of the species is qualified by the number of fires, the time and frequency of burning and the maturity of the plants. Were data available, fire temperatures would be specified also.

\* The term 'fire-tolerant' is preferred here to 'fire-resistant', because a thicket-forming species can be said to 'resist' fire by virtue of its growth habit, and yet it may be killed readily if ever fire penetrates this defence.

*Factors controlling fire susceptibility*

The basic factors which determine the reaction of a plant to fire are the intensity of the fire and the morphology and physiological condition of the plant. All other variables act through their effects on one or other of these factors and some, such as the number and frequency of fires in a burning régime, which have already been discussed, affect both fire intensity and plant condition. Other aspects on which the experiment yielded data are given here by reference to these two heads.

*Fire intensity*

Fire intensity is controlled by the quantity and nature of the combustible material, the meteorological conditions and the technique of ignition. The present data suggest that 1 ton of dry grass per acre is sufficient to give a good fire, and that temperatures can be higher (and more effective) locally around combustible dead stems (see below). The best method of ignition depends on circumstances. Theoretically, area-ignition 'increases the heat and burns more bush than a single line of fire moving across the area' (Heady 1960), but in 1959, when the grass cover was patchy, area-ignition was disappointing and observation on an adjacent plot suggests that ring-burning would have been better. Certainly, a broad line of fire moving with the wind can carry more easily across bare patches and reach up further into the bush-canopy.

*Plant condition*

The condition of the plant, in the sense outlined, is determined primarily by its age, external morphology and surface anatomy and the physical environment. The individual criteria which this study suggests are closely linked to fire susceptibility are the size of the stem base or crown and the number, size and rate of growth of the new shoots produced after burning.

The most fire-tolerant of the species studied, *Acacia brevispica*, has a large crown, and after burning it produced a relatively small number of very vigorous shoots. The most fire-intolerant species, *Acalypha* and *Crotalaria*, have smaller crowns and produced large numbers of small shoots. *Maytenus*, which was semi-tolerant of fire, also produced rather many shoots, but in this species the crown is large, and in addition the temperatures to which the new shoots were exposed were not increased by the burning amongst them of highly combustible dead stems, as was the case in *Acalypha* and *Crotalaria*. *Aspilia* formed shoots in much the same manner as *Acacia brevispica*, though its crown is smaller and the shoots grew only half as rapidly (2–3 ft in 1 year).

These results clearly suggest that a species which forms shoots freely after a first burn will be sensitive to fire later. If the plant is able to support a large number of rapidly-growing shoots (as in *Maytenus*), it may not become fire-sensitive, but the fire-tolerant species characteristically produce a limited number of vigorous shoots which rapidly grow taller than the grass. However, if a plant which regenerates in this way has a relatively small root system (as in *Aspilia*), it may temporarily become fire-sensitive. The presence of highly combustible stems may be critical, particularly if the shoots are small.

These criteria were observed as species characteristics. Information on predisposing factors within a species is confined to the size and age of plants. The intolerance of fire of seedling plants of *Aspilia* (Table 3) is soon lost and the individual plant data provide

no evidence that height (in the range 18–72 in.) affects the fire-susceptibility of this species. In *Maytenus*, fire-susceptibility and the size of mature plants were associated: all the plants killed were 8 ft or over in height. (In *Acacia brevispica*, the one or two plants killed were 1½–2 ft.)

#### Practical applications

These observations suggest that the Katumani thicket association developed during a period when fires were infrequent or lacking, and that planned burning can restore upland *Acacia* woodland.

The number of fires required to do this will depend on their intensity and could be more or less than three. How frequent they should be depends on which species are locally dominant. If *Aspilia* is important, annual burning is necessary, whereas with *Acalypha*, *Maytenus* and possibly *Crotalaria*, biennial burning may be sufficient. In unbroken thicket, preliminary slashing would be essential to establish an effective burning rotation rapidly.

In order to minimize damage to the grassland and allow grazing, the interval between burns should be lengthened once a sufficient proportion of the thicket bushes has been killed. If fire-tolerant species such as *Acacia brevispica* remain, it is preferable to remove them by hand or with arboricides rather than to continue burning frequently. In the present observations, burning did not permanently harm the grass but it did decrease the basal cover. The increases suggested in *Themeda triandra* and *Heteropogon contortus* agree with earlier observations (Edwards 1942; Shaw 1957).

In the Machakos area, fire represents an attractive and safe method of clearing secondary thicket. It is attractive because land under thicket has very little grazing value and the cost of burning it, even for 3 years in succession, is small—certainly much less than the cost of hand-clearing (E.A.Shs 50/- per ac at Katumani). It is safe because the rainfall is moderate and the proportion of fire-tolerant species such as *Acacia brevispica* is small. Elsewhere, frequent burning might be more damaging to the grassland, or favour the increase of fire-tolerant components.

#### ACKNOWLEDGMENT

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#### SUMMARY

Observations on two burning regimes extending over 3 years showed that burning can be a practical method of clearing thicket species in *Acacia* woodland under medium rainfall/altitude conditions in Kenya and that the susceptibility of plants to fire depends as much on burning regime as on species. The five main constituent species, each represented by about twenty selected bushes, were equally tolerant of one fire, but differed in susceptibility to subsequent fires. Thus, *A. brevispica* was tolerant of three annual burns but only semi-tolerant of burning in 1958 and 1960; whereas *Aspilia* sp. was tolerant of the latter treatment but sensitive (40% kill) to the former, and *Maytenus putterlickioides* was semi-tolerant (30% kill) of both treatments. Both *Acalypha fruticosa* and *Crotalaria saxatilis* were intolerant of three annual burns (70–80% kill), but *Acalypha* was sensitive to the two burns treatment (60% kill) while *Crotalaria* was tolerant.

In these data, only in *Maytenus* are plant size and fire susceptibility associated (all plants killed were over 8 ft tall), but counts in supplementary quadrats of complete populations of *Aspilia*, in which half were less than 1 ft tall, indicate that seedling plants of this species are intolerant of even one fire. Other factors controlling fire susceptibility are the size of the root crown, the numbers of shoots produced after burning and their rate of growth, and the combustibility of the dead stems: in particular, if numerous shoots appear after a first burn the species is likely to be sensitive to later burns.

The thicket association studied appears to have become established at a time when fires were less frequent or lacking. To restore open woodland frequent burning is necessary initially, with preliminary slashing in dense thicket. Under local conditions, this approach is safe and economic.

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## EFFECTS OF PRESCRIBED BURNING ON CATTLE AND GOAT DIETS

Moses K. Mbui and Jerry Wayne Stuth

### INTRODUCTION

Dense stands of bush severely reduce herbaceous production of rangelands, and much of the browse forage may not be easily accessible to the grazing livestock (Thomas and Pratt, 1967), hence reducing forage production of rangelands. Afoloyan (1970) observed that certain grass species are maintained in the habitat by burning and grazing, while complete protection from burning and grazing enhances the growth of unpalatable grasses and shrubs.

Fire has been a recurrent phenomenon in the development and maintenance of grazing lands in eastern Africa. Under the traditional agricultural and animal-husbandry patterns of the tribes of eastern Africa, most of the intentional burning was carried out during the dry periods. The goal was to extend grass growth into the dry season, encourage seed germination, remove dead herbage, and check woody species (Lemon, 1968; Ndawulu-Seyimba, 1972; Harrington and Ross, 1974; Kinyamario, 1982). Grass burning is practiced by pastoralists to suppress bush encroachment and to take advantage of early regrowth, among other benefits.

Seasonal distribution of rainfall in the range areas of Kenya is erratic. Rangeland herbage is generally of high quality, if not adequate quantity, during and immediately following the rains. As the vegetation matures into the dry season, quality and quantity (particularly of protein) decline rapidly. The use of fire to improve diet quality has been reported. Apart from influencing botanical composition and accessibility of the available forage, burning enhances dietary crude protein (CP) and organic-matter digestibility (OMD) of forage for varying lengths of time (Lemon, 1968; McKay, 1970; Angell, 1983; McGinty et al., 1983). The dietary benefits of prescribed burning are short-lived, typically lasting through the rapid growth periods following the burn (Hilmon and Hughes, 1965; McAtee et al., 1979; Angell, 1983; McGinty et al., 1983).

The objective of this study was to evaluate the effects of prescribed burning on the seasonal dietary CP and OMD of cattle and goats during the first year of the burn.

### SITE AND METHODS

The study was conducted at the National Range Research Station, Kiboko, in an area that had not been used regularly by station livestock or burned since 1972. The study site is located within the basement-system plain of the volcanic-basement complex and the floodplains of the station soils (Michieka and Van der Pouw, 1977).

The climate of Kiboko and the general area fall under the influence of the intertropical convergency zone (Whyte, 1968), characterized by a bimodal rainfall distribution, with rainy seasons from the end of March to mid-May and from the end of October to mid-December (Michieka and Van der Pouw, 1977). The months of January and February are characterized by a short dry period, while the period from June to October is usually extremely dry. A 45-year weather data record from the general area

indicates long-term annual average rainfall, evaporation, and temperature to be 600 mm, 2,000 mm, and 23°C, respectively (Michieka and Van der Pouw, 1977). Based on the monthly rainfall distribution, May and October could be counted as dry months since they average about 30 mm or less.

The study site vegetation is dominated in the tree layer by Acacia senegal, while Hermania alhensis dominates the shrub layer. Other tall, woody species include Acacia spp., Grewia spp., Commiphora spp., Cordia spp., and Balanites aegyptiaca. Solanum incanum, Hibiscus spp., Lantana spp., and Sida ovata are the major subordinates of the shrub layer. Digitaria macroblephara dominates the herbaceous layer, with Bathriochloa insculpta, Chloris roxburghiana, Bothriochloa glabra, Microchloa kunthii, Sporobolus spp., and Panicum maximum as subordinate grass species. Talinum portulacifolium dominates the forb layer.

Two adjacent paddocks were selected based on ocular-similarity rating of the vegetation. The herbaceous-vegetation-similarity index (Sorensen, 1948) as cited by Mueller-Dombois and Ellenburg (1974) for transects in these paddocks ranged from 80% to 94%. These paddocks had not been used regularly by the station livestock or burned since 1972, but they were under infrequent use by livestock and wildlife. One of the paddocks was burned on February 25, 1982, when the prevailing air temperature, relative humidity, and wind speed were 33°C, 40%, and 8.5 km/hr, respectively. Diet-sample collections from these two paddocks started in March after active vegetation regrowth.

Four esophageally fistulated heifers and two esophageally fistulated goats were used to collect diet samples from the two treatment paddocks for two consecutive days per sampling interval. The sampling intervals were twice monthly during the months of active vegetation growth (except in November and December) and once monthly at other periods for one year's duration. The sampling animals were fasted overnight to avoid extrusa contamination. They grazed alternately in the burned and unburned paddocks after the heifers were fitted with extrusa-collection bags (Cook, 1964; Van Dyne and Torell, 1964) and the goats were fitted with rectangular collection sacks (Kamau, 1984). Four heifer-extrusa samples and two goat-extrusa samples per paddock per sampling day were obtained. The diet samples (per collection day) from each animal were air dried separately on wire-screen-bottom racks for two days and later oven dried at 60°C for 24 hours. The samples then were ground in a Wiley mill to pass a 0.5 mm screen, and the subsamples of the ground samples were subjected to chemical analysis. Special note should be made that, since the whole sample was not completely ground, quality estimates represent the most digestible components of the diet.

The dry matter of each diet sample was estimated by oven drying approximately 0.5 g for 12 hours at 120°C. The organic matter (OM) content of each diet sample was estimated by ignition of 0.5 g of the sample in a muffle furnace at 500°C for 4 hours. All the estimates of the dietary components were computed on an organic-matter basis.

Nitrogen (%N) was determined by the micro-Kjeldahl technique (AOAC, 1975). Percent crude protein (CP) was estimated on an OM basis by multiplying percent nitrogen by a constant of 6.25.

In vitro organic-matter digestibility (IVOMD) was determined by using the fermentation stage of Tilley and Terry (1963) and then the neutral-

detergent phase of Van Soest and Wine (1967). Standards of known in vivo OMD were run with the diet samples to correct for variations in laboratory procedures and rumen inoculum to apparent digestibility.

For statistical analysis, the year was divided into six seasons in relation to the rainfall patterns, and the treatment mean effect was burning. A t-test was used to analyze the diet quality data by treatments (burned and unburned) and season to detect differences between treatments at 95% confidence level.

## RESULTS AND DISCUSSION

### Nutritive Value of Cattle Diets

The nutritional data for the diets were aggregated into six distinct seasons based on rainfall patterns, and the nutritional parameters were analyzed within seasons (table 1).

Higher diet-quality values occurred during the wet seasons. These were periods of active plant growth when the grazing animals would have been actively selecting for leafy, green plant material. Kibet (1984) reported the highest percentage of green leaves in the diets of cattle in November, rather than during the months of June to September, from an adjacent pasture to this study site during the same period. The dry season corresponded with the lowest levels of nutritional quality of cattle diets. Periods of advanced plant maturity have been documented as periods of low CP and OMD (Cook and Harris, 1950; Pritchard et al., 1963; Terry and Tilley, 1964; Cook and Harris, 1968; Kothman, 1968; Burzlaff, 1971; Hagggar and Ahmed, 1971; Sims et al., 1971; Houston et al., 1981; Heitschmidt et al., 1982). These periods coincide with seasons when plants shed most of their dead and senescent leaves. The grazing animals' diets have high stem-to-leaf ratios (Kibet, 1984), and the low levels of dietary quality during the dry periods were indicators of reduced live-plant material in the diets.

Burning enhanced dietary CP of cattle throughout the long wet season and into the early long dry season. The positive effect of burning on dietary CP was lost during the late long dry season, picking up again for 1 month after the October rains. The dietary CP values during the dry season were similar for both burned and unburned paddocks. This was an indication of lack of selectivity for green leaves and stems by the grazing animals due to herbage maturity and plant dormancy. Short-lived, high dietary CP lasting through the rapid growth period following burning has been reported (Holman and Hughes, 1965; McAtee et al., 1979; McGinty et al., 1983). However, cattle selected diets of slightly higher CP from the burned paddock than from the unburned paddock.

Burning had positive effects on the dietary OMD during the long wet season and the early short wet seasons; it had no detectable effect ( $P < 0.05$ ) during other seasons. Thus, burning enhanced OMD insignificantly.

### Nutritive Value of Goat Diets

The nutritional quality of goat diets followed a similar seasonal trend as that of cattle except that the variation from one season to the next was not as dramatic (table 2).

Burning had a significant positive effect ( $P < 0.05$ ) on dietary CP in the early short wet season. There was no apparent positive effect of burning during other seasons. However, it is probable that a positive effect would have been detected during the long wet season had samples for the April flush of growth been included in the analyses. Diets from the burned paddock maintained higher trends of CP levels than diets from the unburned paddock in almost all seasons of the study period. It is also apparent that burning increased seasonal variation in the dietary CP in the burned paddock compared to the unburned paddock.

Although goats prefer browse (Harrington, 1982; Rector, 1983; Kamau, 1984), they are not obliged browsers (Harrington, 1982; McDonnell and Woodward, 1982). Thus, goats graze according to the availability and quality of herbage. The abilities of goats to select and consume plant parts of high quality and shift their diets with season are demonstrated by the high quality of their diets in all seasons. The seasonal variation within the burn treatment may have been due to the increase in forb availability, especially Talinum spp. and Hibiscus spp., whose leaves and fruits are relished by goats.

Even though dietary OMD content appeared to be higher in diets from the burned paddock during most of the year, differences could be detected only during the late short wet season ( $P = 0.024$ ), when the dietary OMD content was higher in the diet from the unburned paddock. During the other seasons, OMD of the diets was apparently similar ( $P =$  range of 0.1005 to 0.74). It is apparent that burning did not provide goats with a significantly greater opportunity for selecting more digestible forage due to the fact that goats are able to select the nutrient-rich parts of grasses and browse of higher digestibility from the available forage (Arnold, 1960; Malechek and Leinweber, 1972; Harrington, 1982; McDonnell and Woodward, 1982).

#### SUMMARY

The effect of prescribed burning on the seasonal quality of cattle and goat diets was investigated. Burning enhanced the CP content of cattle diets during the wet seasons and into the early part of the dry seasons. The positive effects of burning were detectable only during the early part of the wet seasons. Detectable positive effects of burning on the OMD of cattle diets lasted for shorter periods than the effects of burning on CP. Burning had detectable positive effects on dietary CP and OMD of goat diets only during the early part of the wet seasons.

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## THE EFFECT OF VELD-BURNING ON THE SEASONAL ABUNDANCE OF FREE-LIVING IXODID TICKS AS DETERMINED BY DRAG-SAMPLING

A. M. SPICKETT<sup>(1)</sup>, I. G. HORAK<sup>(2)</sup>, ANDREA VAN NIEKERK<sup>(1)</sup> and L. E. O. BRAACK<sup>(3)</sup>

### ABSTRACT

SPICKETT, A. M., HORAK, I. G., VAN NIEKERK, ANDREA & BRAACK, L. E. O., 1992. The effect of veld-burning on the seasonal abundance of free-living ixodid ticks as determined by drag-sampling. *Onderstepoort Journal of Veterinary Research*, 59, 285-292 (1992)

A supervised veld-burn in the *Sclerocarya caffra*/*Acacia nigrescens* Savanna landscape zone in the south-eastern region of the Kruger National Park was carried out during September 1988. The effect of the fire on the free-living tick population was determined by comparing the numbers of ticks collected by monthly drag-sampling in the burnt zone with those collected in an adjacent unburnt zone over a 2-year period. A total of 13 ixodid tick species were involved.

Tick numbers were reduced after the burn but rose again after varying periods of time. The length of these periods depended upon a number of variables. These included tick species, patterns of seasonal abundance, and host preferences. The original reduction in numbers seemed to result in subsequent cyclical population fluctuations and in some instances overcompensation was noted.

Veld-burning as a control technique may be effective with tenuously adapted tick species or reduced populations and may be enhanced by the exclusion of major hosts for a critical period after the fire.

### INTRODUCTION

The value of veld-burning as a means of controlling tick populations has mostly been a matter of conjecture and its use to date mainly haphazard. Theiler (1959, 1969), theorized that veld-burning does not destroy the developing stages but rather increases environmental exposure, resulting in shortened developmental periods. Minshull & Norval (1982) found that fire affected the distribution of all tick stages because of the increased density of grazing herbivores on recently burnt areas. Traditional winter burning practised by farmers to encourage new growth, does not coincide with the seasonal activity periods of the questing stages of most ixodid ticks (Norval, 1977). This, coupled with the environmental harm caused by winter burning according to agronomists, has resulted in the practice generally being considered an unsuccessful biological control measure for ticks (Galun, 1978).

The scientifically planned, routine, supervised veld-burning of certain regions in the Kruger National Park, eastern Transvaal Lowveld, presented an opportunity to monitor the long-term effect of fire on the questing stages of ticks compared to those on an adjacent unburnt area.

### MATERIALS AND METHODS

#### Study site

The study was carried out in the extreme south of the *Sclerocarya caffra*/*Acacia nigrescens* Savanna zone (Landscape Zone 17 of Gertenbach, 1983) of the Kruger National Park. A full description of the

geomorphology, climate, soil and vegetation patterns of this region has been provided by Gertenbach (1983). Generally it is an open, tree savanna with a moderate shrub and dense grass layer. The study site lies within an area described as tropical with an above average rainfall for this zone, i.e. the long term average for the nearest station, Crocodile Bridge, is 599,6 mm. The study site encompassed an area approximately 20 × 10 km in extent (25° 10'–25° 21' S and 32° 02'–32° 05' E), along the Nhlowa tourist road, between Crocodile Bridge in the south and Lower Sabie in the north. The southern portion of this area, immediately to the west of the road, was subjected to a total veld-burn during the second week of September 1988. The northern portion of the area, to the east of the road, was utilized as the unburnt control zone. The burnt and unburnt zones displayed no obvious differences in topography or vegetation.

#### Tick collection

Ticks questing on the vegetation were collected by drag-sampling (Zimmerman & Garris, 1985; Petney & Horak, 1987). A detailed description of our collection method is given in Spickett, Horak, Braack & Van Ark (1991). In addition a 95 mm long steel rod was sewn into the end of each flannel drag strip to aid in keeping these down on the vegetation while dragging, and flannel leggings were also worn. The latter consisted of 2 flannel strips, sewn together at the waist, and covering the front of the drag operator from the waist to the ankles. The leggings were tied to the operator at the waist, knees and ankles and provided an additional surface for the attachment of questing ticks while the drag strips were being pulled through the vegetation.

Three drags were performed in each of 3 representative subzones within both the burnt and unburnt zones. These subzones were open grassland, gully and woodland. The collections were usually made on the same day in the first week of each calendar month, commencing in August 1988,

<sup>(1)</sup> Onderstepoort Veterinary Institute, Private Bag X05, Onderstepoort 0110

<sup>(2)</sup> Faculty of Veterinary Science, University of Pretoria, Onderstepoort 0110

<sup>(3)</sup> National Parks Board, Private Bag X402, Skukuza 1350

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## EFFECT OF VELD-BURNING ON THE SEASONAL ABUNDANCE OF FREE-LIVING IXODID TICKS

TABLE 1 The total number of ticks recovered over a 2-year monitoring period from the vegetation of a burnt and an unburnt zone in the Kruger National Park

	Larvae	Nymphs	Males	Females	Total
<b>Burnt zone</b>					
<i>Amblyomma hebraeum</i>	10 979	13	0	0	10 992
<i>Amblyomma marmoreum</i>	11	0	0	0	11
<i>Boophilus decoloratus</i>	5 395	0	0	0	5 395
<i>Haemaphysalis leachi</i>	14	0	22	12	48
<i>Rhipicephalus appendiculatus</i>	2 810	87	9	6	2 912
<i>Rhipicephalus evertsi evertsi</i>	1 233	0	0	0	1 233
<i>Rhipicephalus simus</i>	1	2	6	11	20
<i>Rhipicephalus turanicus</i>	0	0	2	4	6
<i>Rhipicephalus zambeziensis</i>	229	5	0	0	234
Totals	20 672	107	39	33	20 851
<b>Unburnt zone</b>					
<i>Amblyomma hebraeum</i>	27 608	11	0	0	27 619
<i>Amblyomma marmoreum</i>	58	1	0	0	59
<i>Boophilus decoloratus</i>	5 405	0	0	0	5 405
<i>Haemaphysalis leachi</i>	7	1	9	8	25
<i>Haemaphysalis sp.</i>	1	0	0	0	1
<i>Hyalomma truncatum</i>	4	0	0	0	4
<i>Ixodes sp.</i>	0	1	0	0	1
<i>Rhipicephalus appendiculatus</i>	7 477	93	6	5	7 581
<i>Rhipicephalus evertsi evertsi</i>	352	0	0	0	352
<i>Rhipicephalus maculatus</i>	0	1	0	0	1
<i>Rhipicephalus simus</i>	1	0	13	21	35
<i>Rhipicephalus turanicus</i>	0	0	6	2	8
<i>Rhipicephalus zambeziensis</i>	116	20	0	0	136
Totals	41 029	128	34	36	41 227

for a period of 2 years. A controlled, hot veld-burn of the designated zone, to burn off the existing dense vegetation layer, was supervised by National Parks Board staff after the September 1988 drags had been completed in both study areas.

Ticks collected monthly in the subzones from the flannel drag strips plus the leggings were identified and totalled separately for the burnt and unburnt zones. These counts were transformed [ $\text{Log}_{10}(x + 1)$ ] and, where applicable, differences between monthly collections were analysed using the non-parametric Wilcoxon paired observation test (Petney, Van Ark & Spickett, 1990). Each monthly total therefore represents questing ticks recovered from 9 drags in each zone.

## RESULTS

The collection method used favours the recovery of larvae (Spickett *et al.*, 1991) although nymphs and/or adults of some species were consistently recovered. The tick species and total numbers recovered from the vegetation of the burnt and unburnt zones of the study area during the 2-year monitoring period are summarized in Table 1.

In total, 13 tick species were collected, the unburnt zone yielding small numbers of 4 species not recovered in the burnt zone. These were *Haemaphysalis sp.* (1 larva), *Hyalomma truncatum* (4 larvae), *Ixodes sp.* (1 nymph) and *Rhipicephalus maculatus* (1 nymph). Of the remaining 9 species, 6 were more numerous in the unburnt zone than in the burnt zone, some significantly so and others only marginally. The 3 species which were more numerous in the burnt zone than in the unburnt zone were *Haemaphysalis leachi*, *Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis*.

In the burnt zone the order of predominance of the species (and developmental stage recovered) was,

*Amblyomma hebraeum* (larvae) followed by *Boophilus decoloratus* (larvae), *Rhipicephalus appendiculatus* (larvae), *R. evertsi evertsi* (larvae), *R. zambeziensis* (larvae), *H. leachi* (adults), *Rhipicephalus simus* (adults), *Amblyomma marmoreum* (larvae) and *Rhipicephalus turanicus* (adults). In the unburnt zone this order was *A. hebraeum* (larvae), *R. appendiculatus* (larvae), *B. decoloratus* (larvae), *R. evertsi evertsi* (larvae), *R. zambeziensis* (larvae), *H. leachi* (adults), *A. marmoreum* (larvae), *R. simus* (adults) and *R. turanicus* (adults). The burnt zone yielded about half the total number of ticks recovered in the unburnt zone.

The monthly total numbers of ticks (irrespective of species) collected from the burnt and unburnt zones are graphically illustrated in Fig. 1. An initial drop in

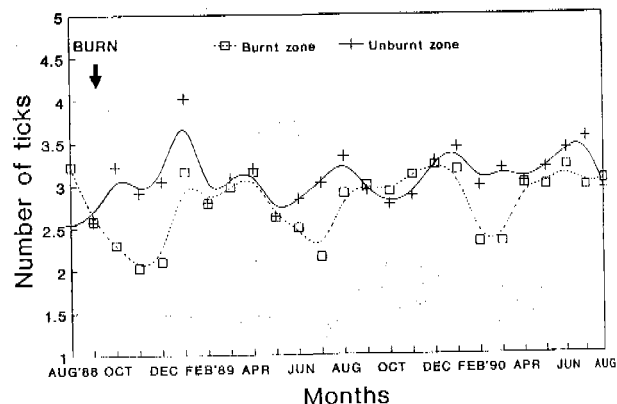


FIG. 1 The monthly total numbers of ticks [ $\text{Log}_{10}(x + 1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag



numbers occurred in the burnt zone immediately after the fire. These started to increase 4 months later and reached levels similar to those in the unburnt zone 5 months after the burn. However, cyclic declines in tick numbers in the burnt zone occurred at 10 and 17 months and a marginal overcompensation at 13 months after the burn. Paired analysis of monthly collections showed the total number of ticks collected in the burnt zone to be significantly less than in the unburnt zone ( $P=0,005$ ;  $T=52,0$ ).

The numbers of *A. hebraeum* larvae recovered are illustrated in Fig. 2. No change in numbers was recorded in the burnt zone 1 month after the fire, while those in the unburnt zone rose sharply. Thereafter the fluctuations in larval numbers paralleled each other with the totals in the 2 zones being nearly equal 6 and 7 months after the burn. This was followed by 4 sharp declines in larval numbers interspersed by short periods of recovery in the burnt zone. The initial reduction in numbers coupled with these declines resulted in less than half the number of *A. hebraeum* larvae being recovered from the burnt zone than from the unburnt zone (Table 1). Paired analysis of monthly collections indicated larval numbers in the burnt zone to be significantly less than in the unburnt zone ( $P=0,009$ ;  $T=65,0$ ).

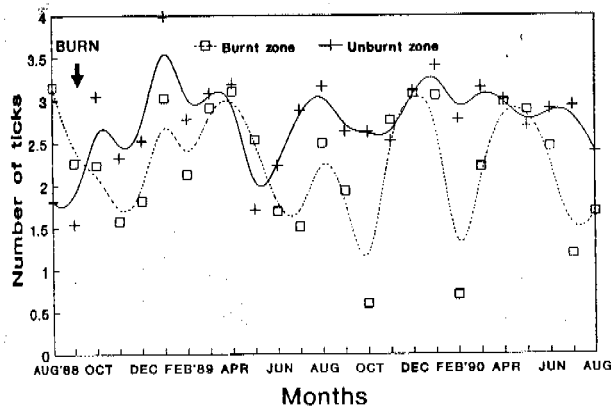


FIG. 2 The monthly total numbers of *Amblyomma hebraeum* larvae [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

In the burnt zone, *A. marmoreum* larvae were recovered in August 1988 before the burn and only again in January, April and June 1990, 16–21 months after the burn. In the unburnt zone larvae were active from March–September 1989 and from March–June 1990 (Fig. 3). The numbers of larvae recovered from the burnt zone during the 2-year monitoring period were significantly less than in the unburnt zone on paired analysis of monthly collections ( $P=0,021$ ;  $T=9,5$ ).

*B. decoloratus* larvae declined sharply in the burnt zone immediately after the burn and increased equally rapidly to nearly equal the number of those in the unburnt zone within only 4 months (Fig. 4). A 3

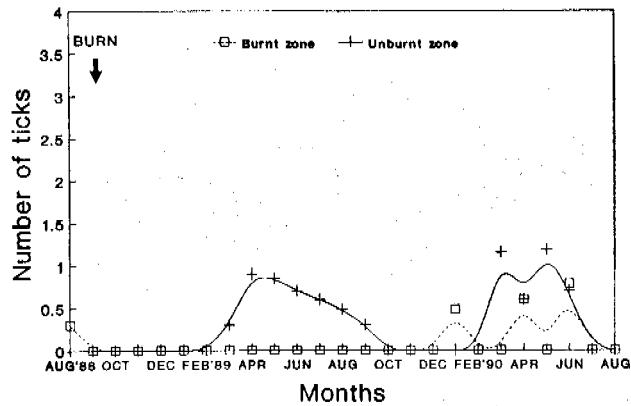


FIG. 3 The monthly total numbers of *Amblyomma marmoreum* larvae [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

month period of overcompensation followed this recovery in the burnt zone, while larval numbers in the unburnt zone underwent a seasonal decline. The subsequent decline in larval numbers in the burnt zone reached its lowest level 4 months after that in the unburnt zone. The increase in larval numbers following this decline was more rapid in the burnt than in the unburnt zone. Overcompensation resulted in peak abundance 2 months prior to that in the unburnt zone. After this, larval numbers in both zones stabilized and for approximately 6 months remained similar though fewer were recovered in the burnt zone. Larvae in the latter zone displayed another peak during June 1990, 21 months after the burn had taken place. A total of only 10 fewer *B. decoloratus* larvae were recovered from the vegetation of the burnt zone than that of the unburnt zone (Table 1). Despite the fluctuations in the numbers recovered monthly (Fig. 4), paired analysis showed no significant difference between the burnt and unburnt zones ( $P=0,542$ ;  $T=139,5$ ).

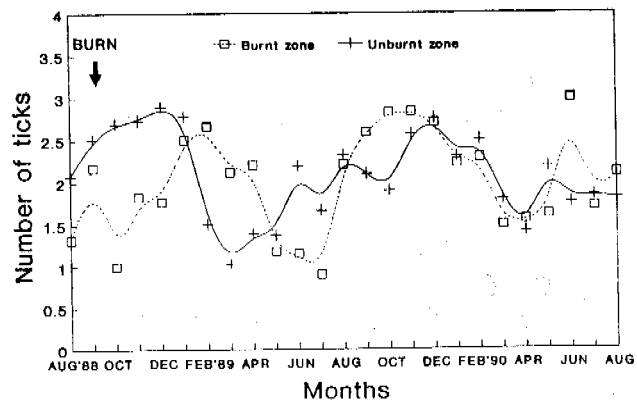


FIG. 4 The monthly total numbers of *Boophilus decoloratus* larvae [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

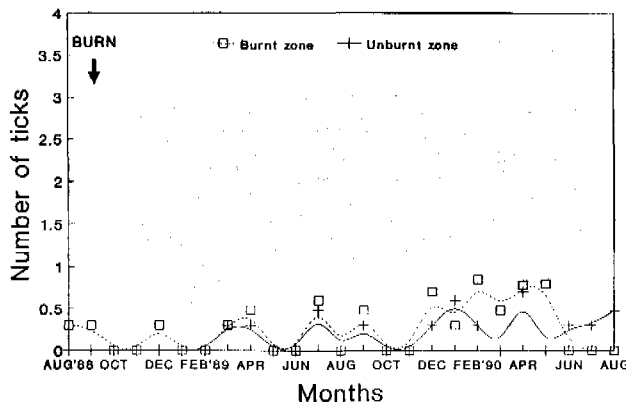


FIG. 5 The monthly total numbers of *Haemaphysalis leachi* adults [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Cyclic variations in the small numbers of adult *H. leachi* recovered were evident in both the burnt and unburnt zones (Fig. 5). Slightly more adults were recovered in the burnt zone, especially during the second year of observation. These numbers were considered too small for meaningful analysis.

The larvae of *R. appendiculatus* were in a seasonal population decline at the time of the burn and no effect on larval numbers or seasonal activity was evident (Fig. 6). In both burnt and unburnt zones the larval activity period spanned 8 months, from April to November 1989. Peak abundances were recorded during May or June to August 1989, and activity commenced again in March or April 1990 and peaked in July. The numbers of larvae recovered from the burnt zone were consistently, as well as significantly less than those from the unburnt zone ( $P=0.0028$ ;  $T=16.5$ ).

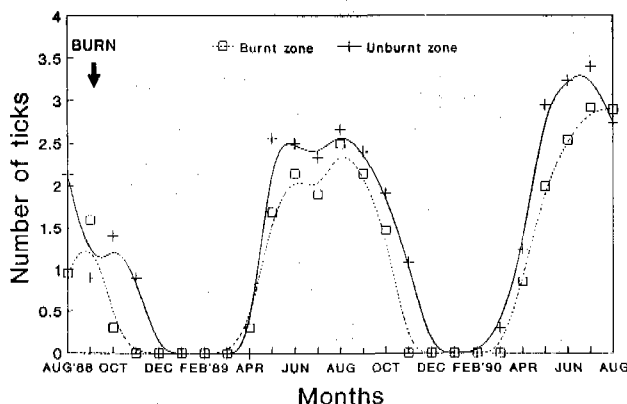


FIG. 6 The monthly total numbers of *Rhipicephalus appendiculatus* larvae [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Small numbers of *R. appendiculatus* nymphs were recovered from both burnt and unburnt zones (Table 1). A marked decline in nymphal numbers was evident immediately after the burn in the burnt zone. However, nymphal activity in this zone continued for 2 months thereafter and ended only 2 months prior to that in the unburnt zone (Fig. 7). Subsequent resumption of nymphal activity occurred marginally sooner in the burnt zone than in the unburnt zone and reached slightly higher numbers, but with a shorter period of peak abundance. The unburnt zone yielded only 6 more nymphs in total than the burnt zone and paired analysis of monthly collections indicated no significant difference in the numbers recovered ( $P=0.465$ ;  $T=76.5$ ).

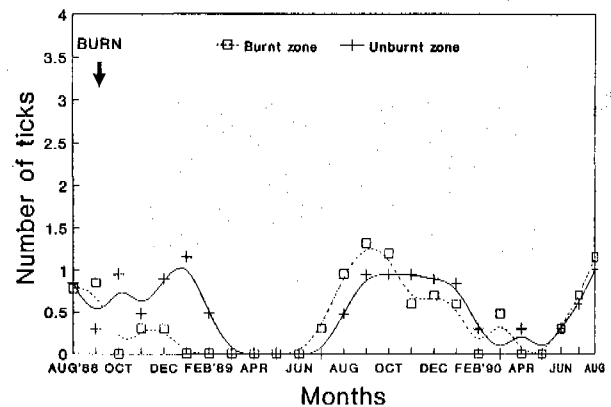


FIG. 7 The monthly total numbers of *Rhipicephalus appendiculatus* nymphs [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

*R. appendiculatus* adults, although present in the unburnt zone, were not collected in the burnt zone until 7 months after the burn had taken place (Fig. 8). Thereafter adults were collected in low numbers in this zone for 2 months only, before their seasonal

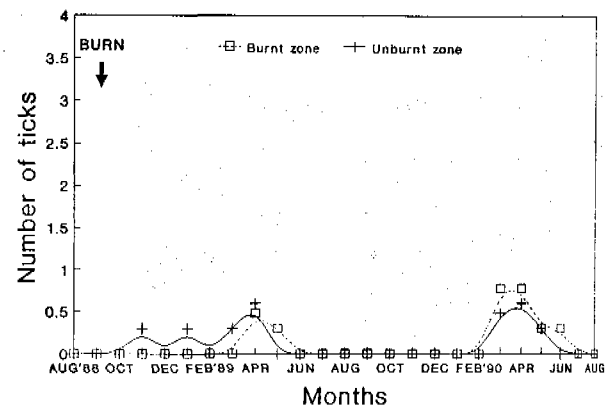


FIG. 8 The monthly total numbers of *Rhipicephalus appendiculatus* adults [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

decline in June 1989. Adult activity resumed in both zones from March to May or June of the next year. The numbers collected were too low for meaningful analysis of differences.

*R. evertsi evertsi* displayed cyclic activity throughout the monitoring period with no definite pattern of seasonal abundance (Fig. 9). No larvae were recovered in the burnt zone in September 1988 immediately preceding the burn. Their numbers increased thereafter to reach numbers similar to those in the unburnt zone within 4 months. A cyclic 2-month pattern of high and low numbers followed, similar to that in the unburnt zone but with larger fluctuations. Consistently higher numbers of larvae were recovered from the burnt than from the unburnt zone during the period September 1989 to January 1990 (12 to 16 months after the burn) and again from April 1990 to August 1990 (19 to 23 months after the burn) (Fig. 9). This resulted in approximately 4 times more *R. evertsi evertsi* larvae being recovered from the burnt than from the unburnt zone (Table 1). Paired analysis of monthly collections, however, showed no significant differences in larval numbers between the 2 zones ( $P=0,200$ ;  $T=114,5$ ).

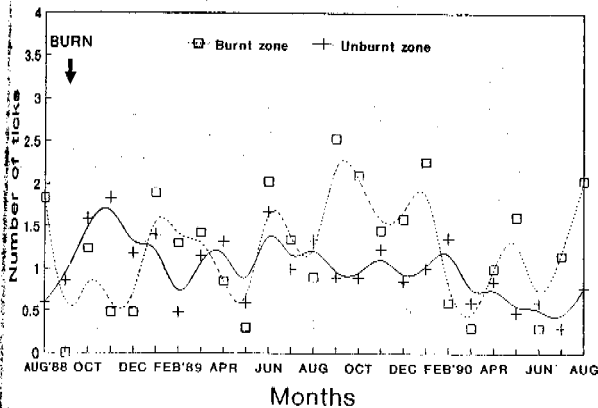


FIG. 9 The monthly total numbers of *Rhipicephalus evertsi evertsi* larvae [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Low numbers of *R. simus* adults were present from December or January to May in both years, in both the burnt and unburnt zones (Fig. 10). The burn seemed to have some effect in that no adults were collected in the burnt zone during the earlier portion of the first activity period (up to 7 months after the burn). The second activity period (16 months after the burn) appeared to be shorter in the burnt than in the unburnt zone. The numbers of adults collected were too low for meaningful analysis.

The numbers of adult *R. turanicus* recovered in both zones were too low to permit meaningful analysis.

The larval population of *R. zambeziensis* was in a period of seasonal decline at the time of the burn (Fig. 11). The burn therefore had very little effect

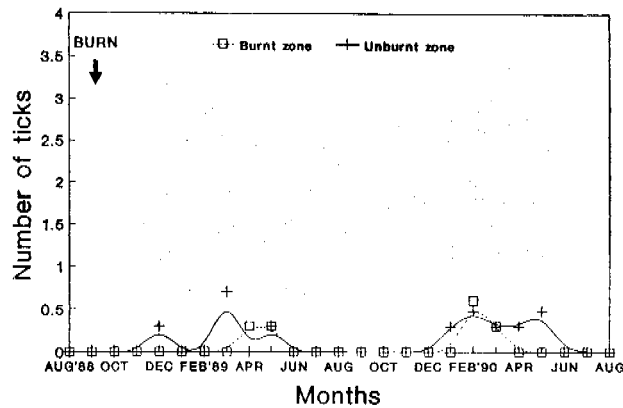


FIG. 10 The monthly total numbers of *Rhipicephalus simus* adults [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

except perhaps that larval activity was less pronounced during the subsequent activity period May 1989 to September 1989 (8 to 12 months after the burn). Larval numbers had stabilized by the next season, in which activity commenced during May 1990 (20 months after the burn) and lasted till the end of the monitoring period. Paired analysis of monthly collections revealed no significant difference in larval numbers between the 2 zones ( $P=0,726$ ;  $T=24,0$ ).

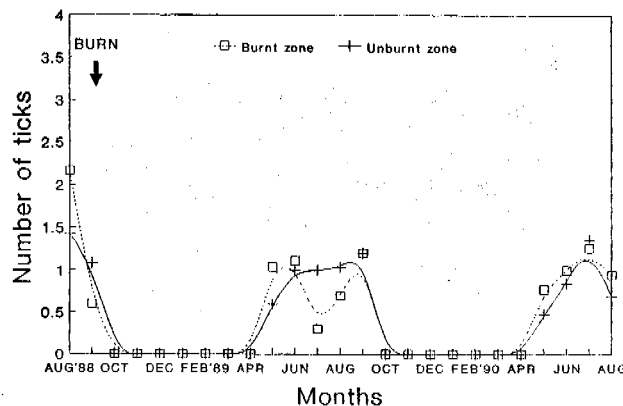


FIG. 11 The monthly total numbers of *Rhipicephalus zambeziensis* larvae [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

*R. zambeziensis* nymphs were recovered from the burnt zone before and in the month immediately after the burn (Fig. 12). Thereafter none were found for the remainder of the monitoring period. In contrast, *R. zambeziensis* nymphs recovered from the unburnt zone, albeit in low numbers, displayed activity over the winter and spring months, from August to November 1989. Although adults of *R. zambeziensis* have previously been collected in other land-

## EFFECT OF VELD-BURNING ON THE SEASONAL ABUNDANCE OF FREE-LIVING IXODID TICKS

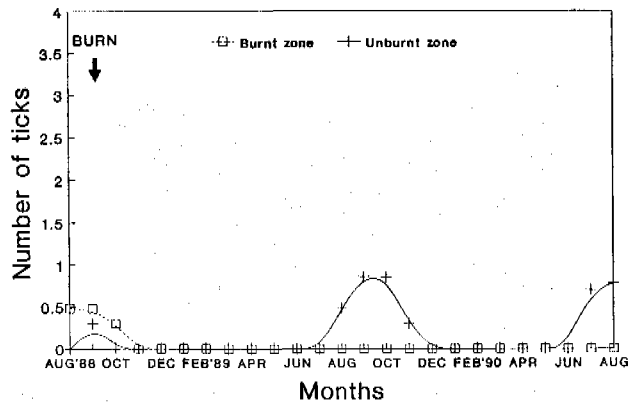


FIG. 12 The monthly total numbers of *Rhipicephalus zambeziensis* nymphs [ $\text{Log}_{10}(x+1)$ ] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

scape zones using the same sampling technique (Spickett *et al.*, 1991), no adults were recovered in this study from the burnt or unburnt zones.

#### DISCUSSION

It could be expected that a hot veld-fire would destroy virtually all free-living tick stages present at the time. However, even the first drags after the burn, which were conducted after a 3-week interval, yielded ticks from the vegetation of the burnt zone. The larvae present on these first drags must have survived the burn or have hatched within the 3-week interval from eggs that were present at the time of the burn. The relatively short period of 4–5 months for the recovery of the free-living tick population as a whole in the burnt zone, after its initial decline, also indicates that some eggs and perhaps even engorged females had survived the effects of the fire. The initial reduction caused by the burn did, however, affect overall tick numbers in that 2 further cyclic declines were evident in the burnt zone, 10 and 17 months after the fire, resulting in significantly fewer ticks being recovered from this zone than from the unburnt zone.

The effects of the burn on the total tick population are largely a reflection of its effects on the 3 major species viz., *A. hebraeum*, *B. decoloratus* and *R. appendiculatus*. These and *R. evertsi evertsi* and *A. marmoreum*, were the most drastically affected in respect of numbers recovered or seasonal activity. The increase in larval numbers of *A. hebraeum* and *B. decoloratus*, after their initial decline in the burnt zone, is probably a result of exposure of their eggs to higher temperatures after removal of the vegetation layer and hence more rapid hatching. The overcompensation in the number of *B. decoloratus* larvae exhibited in the fifth to seventh month after the burn, is most likely due to the relatively early hatch of eggs from engorged females, detached from hosts which had been attracted to the burnt zone by new growth, 2 to 5 months previously. Because of the absence of vegetation cover, soil sur-

face temperatures would have been higher and oviposition and egg hatch could have been completed within the space of 2 months (Robertson, 1981; Spickett & Heyne, 1990). The continued attraction of herbivores to the new growth in this zone during the following months would have contributed more engorged female *B. decoloratus*. The increased protection afforded to these females by the developing vegetation cover, as well as the onset of winter would delay oviposition and consequently egg development. The synchronous hatching of these eggs in spring (Robertson, 1981; Spickett & Heyne, 1990), could account for the next period of overcompensation in larval numbers from September to November 1989, 12 months after the burn.

The same host attraction effect is evident in the higher numbers of *R. evertsi evertsi* recovered from the burnt zone during the latter portion of the monitoring period. Grazers utilizing long grass would have frequented the burnt zone only after an extended period of recovery of the vegetation layer. The increased presence of these animals and particularly zebras, which are the preferred hosts of *R. evertsi evertsi* (Horak, De Vos & De Klerk, 1984), in the burnt zone some time after the fire would have resulted in many engorged females being dropped and consequently an increase in larvae during the second half of the monitoring period. The greater number of adult *H. leachi* in the burnt zone compared with the unburnt zone during the latter portion of the monitoring period can possibly be ascribed to carnivores, which are the preferred hosts of this stage (Horak, Jacot Guillarmod, Moolman & De Vos, 1987), following the grazers into the zone with the development of new growth in the previous year.

An opposite effect of the burn on the hosts and hence on tick numbers is clearly illustrated in the case of *A. marmoreum*. Larvae were recovered in the burnt zone for the first time 16–21 months after the burn, whereas activity occurred in the unburnt zone 4–10 months earlier and also during the 18–21 month period after the burn had taken place. The preferred hosts of *A. marmoreum* adults are tortoises (Norval, 1975). Many of these were probably destroyed in the fire and, judging by larval activity, only moved back into the zone approximately 10–12 months later. This is, however, another explanation for this phenomenon. All parasitic stages of *A. marmoreum* may spend several months on their tortoise hosts (Dower, Petney & Horak, 1988), and hence the life-cycle may be longer than 1 year. Any disruption of this life-cycle, such as the destruction of the free-living stages by fire, might therefore result in a period of a year or more for the cycle to be rectified.

The normal seasonal fluctuations of the various life stages of the tick populations at the time of the burn also played a role in the direct or long-term effect of the fire. In contrast to *A. hebraeum* and *B. decoloratus*, the larval populations of both *R. appendiculatus* and *R. zambeziensis* were in a state of seasonal decline at the time of the burn. The fire to a small extent accelerated this decline and also indirectly reduced larval numbers of *R. appendiculatus* during the subsequent activity periods. However,

The onset of the subsequent larval activity period of both species was not affected. The effect of the burn on the nymphs of the latter 2 ticks was direct at the time of the burn. This and the direct effect on the larvae at the same time affected both subsequent nymphal activity and numbers and the nymphs of *R. zambeziensis* disappeared entirely from the burnt zone. The absence of adult *R. appendiculatus* during their normal activity period after the burn was probably a consequence of the free-living nymphs being destroyed by the fire. No adult *R. zambeziensis* were collected from either zone during the monitoring period.

The large numbers of *R. appendiculatus* compared to the small numbers of *R. zambeziensis* recovered from both burnt and unburnt zones, indicate that the former species is ecoclimatically favoured in this landscape zone, while the presence of the latter is tenuous. The fire thus affected the less secure species to a greater extent resulting in the disappearance of *R. zambeziensis* nymphs from the burnt zone. Adult *R. simus*, like adult *R. appendiculatus*, appear to be affected only directly after the burn with a minimal, if any, effect on numbers during the second activity period. The virtual absence of the immature stages of both *R. simus* and *H. leachi* on the drags can be ascribed to their questing behaviour. Both prefer rodents during these stages of development (Norval, 1984; Hussein & Mustafa, 1985) and would hence be unlikely to quest from vegetation.

The presence of 4 additional tick species in the unburnt zone is probably unrelated to the effects of veld-burning. The recovery of only 4 *H. truncatum* larvae, despite their occurrence in large numbers on scrub hares in the Park (Horak & Spickett, unpublished data), confirms the inability of the sampling technique employed to adequately monitor this species (Spickett *et al.*, 1991). The collection of a nymph of *R. maculatus* is surprising as its distribution is confined to the coastal regions of northern Natal (Walker, 1991). This species could have been introduced into the Kruger National Park with hosts transferred to the Park from Zululand. Its subsequent establishment in the Park has been confirmed by the recent recovery of a male and an engorged female from an elephant in the Park (L.E.O. Braack, unpublished data).

The temporary and generally short-lived reductions in tick populations recorded after the fire in the present study, indicate little practical benefit from veld-burning during spring as a method of tick control. The effects of fire are influenced by the developmental status of the tick population at the time of the burn, subsequent host influx or exclusion from the burnt area, and the ecoclimatic suitability of the region for tick species. The technique may, however, be effective if aimed at specific tick species, either tenuously adapted to an area or with populations already reduced by chemical control. Efficacy could be enhanced by the exclusion of major hosts for a critical period after the burn to prevent or delay population recovery, a strategy advocated by Minshull & Norval (1982).

#### ACKNOWLEDGEMENTS

We wish to express our very sincere thanks to the National Parks Board of Trustees for placing the extensive facilities in the Kruger National Park at our disposal. We are extremely grateful to Miss Heloise Heyne for assistance with data collection and Messrs Danie de Klerk, Alfred Nkuna, Solomon Monareng and Robert Mathebula as well as the nature conservation students, Ian de Beer, Neil Mostert, Adriaan Louw, Julian Simon and Garth Nielson, ably assisted with the collection of ticks from the flannel strips. The students also acted as gun-bearers for our protection during the drag-sampling procedure. This study was funded by the Foundation for Research Development, the National Parks Board, the Onderstepoort Veterinary Institute and the University of Pretoria.

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Consultancy Report for Save the Children Federation - USA

## **Restoration of Grazing Lands in the Liben Woreda, Borana.**

Consultancy  
October 12-November 1, 2000

Report  
November 4, 2000

by

G. Allen Rasmussen, Ph.D.  
Department of Rangeland Resources  
Utah State University  
Logan, Utah 84322-5230

This report submitted in partial fulfillment of the consulting agreement with Save the Children Federation, Inc.

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**General duties requested to be completed listed in schedule A of the Consultancy Contract:**

- 1) participate in a bush clearing pilot project involving pastoralist communities of the Liben-Borana Zone of Ethiopia.
- 2) produce a comprehensive report on the quality of SCF's work thus far and make recommendations as to how to improve the professional quality of the implemented activities.

**Specific tasks included:**

- a) Review previous consultancy reports related to activity.
- b) Make detailed field visits to become acquainted with the ecosystem, in order to assess the character and impact of the different bush types on grazing land, affecting the lives of pastoralists.
- c) Reviewing the planning and techniques employed in pasture improvement activity for technical soundness, cost-effectiveness, and sustainability.
- d) Provide comments and recommendations on efficient techniques in pasture improvement, through clearing undesirable bush and maintenance of healthy productive rangeland ecosystems to ensure sustainability of projects.
- e) Reviewing SCF/US's DAP pasture improvement activity for impact on environmental as well as human and livestock populations.
- f) Provide recommendations that lead to better implementation of the project and more effective realization of its objectives.

In addition, the field staff at Negelle requested that I provide:

- g) Provide a one-day seminar on rangeland management.

## Completion of tasks

### Task A Review of previous reports.

Ms. Joyce LeMelle and Mr. Wakgari Alemu provided me previous reports. These included Eco-consult 1997, Alemu 2000, Jemal and Menzel 1997, SCF/US DAP 1997 and SCF/US DAP amendment 2000. These were reviewed before field visits were started on October 17, 2000. Only the grazing land restoration portions of the DAP's were reviewed before field visits. In addition, I reviewed the following documents while in Negelle: GTZ-BLPDP, ZADD 1998a and b, Oba 1998a and b).

### Task B Field Visits.

I visited eight field sites with Mr. Alemu. These sites represented the *Acacia-Commiphora*, *Sericocompsis-Combretum*, Wooded grassland, and *Terminalia-Commiphora* communities. These plant communities represented approximately 75% of the district (Eco-consult 1997). The field sites were in the following PAs: Jidola, Gannale, Mi'essa, Kobadi, Hadhessa, Qorattie, Bulbul and Boba. In addition, we meet with 4 groups of elders (9 total) in these regions to get an understanding of what they would be willing and capable of implementing as well as maintain in the future. I also met with local NGO's and GO's for their input on these activities. The input from these groups was desired for their views on the sustainability of the projects. See Appendix A for a detailed description of the field visits.

### Task C. Pilot Study.

Eco-consults (1997) listed four techniques (scenarios), which could be used to restore the grazing lands of the Liben Woreda. Mr. Alemu and I evaluated the pilot project described in the DAP (1998), to assess the environmental impact of the techniques in the local area. The pilot project was conducted in the wooded grassland plant community because of the higher potential for restoring the grasslands.

The overall impact of the pilot project, from both an environmental and social aspect, was highly positive. The most impressive impact was the buy in from the local community to implement all of the management changes the pilot required. This was particularly important with the alteration of the livestock grazing management. Even during the current drought the ground cover has increased and the hydrologic conditions have improved compared to those areas outside of the pilot. Because of the altered livestock grazing management all techniques improved hydrologic conditions. In addition the reduction of the invading noxious shrubs was significantly reduced. This plus the improved grazing management provides the opportunity to restore the original grasslands that once dominated these areas. Mr. Alume did an outstanding job in developing the study were it can be statistically analyzed. See appendix B for a detailed description and additional recommendations.

#### Task D. Future Pilots that could help other communities.

The current pilot shows some very promising results and I applaud the professional approach that was applied. The current pilot was done during a drought. The success of the current pilot could be caused by these weather conditions. This study should also be continued during a normal precipitation year to determine the potential success during these conditions. I would not stop the implementation of the current recommendation but use the additional study as a supplement to refine the current recommendations.

The *Acacia* and *Sericocomopsis* communities have very little herbaceous grass cover left. These areas would require a couple of extra steps after cutting to reestablish a grassland community. Fire could then be used to maintain the system. However, I would prioritize those sites that still have some grass in the understory. The input required to move these types of communities back to a grassland makes it unlikely the local people will be able to sustain any longterm changes or convert a significant number of ha (Figure 2). The bush is capable of resprouting and has sufficient growth characteristics that grass would not have a chance to reestablish in most cases.

An alternative idea would be to try reducing the competitive advantage of the bush and shift the advantage back to the grasses. This could be started as a pilot with the following steps.

- 1) Clear 2 ha of bush using the stump cut method described in the initial pilot study done on the wooded grasslands (appendix b). Then use the shrub branches to create a fence that would be used, first to keep goats in, then to keep all livestock out while grasses are established.
- 2) Graze the area heavily with goats before the thorns on the resprouts have had a chance to harden. This would have to be done whenever the resprouts grew to about 4-5 centimeters. This would have to be watched closely, particularly during the wet seasons. Based on the local experience this could be as many as six to eight times during the year. My past experience indicates this would take about 15 goats and/or sheep 1-3 days. This would have to be watched closely. If the animals are removed too soon, the resprouts thorns will harden and make subsequent animal use difficult.
- 3) After the second year (or when it is noticed that the resprouts growth and establishment have slowed) stop grazing and allow the herbaceous vegetation a chance to establish. If there are not sufficient grasses in the area, reseeding will be required.
- 4) Fire could then be used to maintain the area. This method will be slow but with patience a community with access to about 100 goats and sheep could

work on 20/50 ha per year. This would allow the existing cattle a better supply of forage and subsequently more nutrition for the people in the area. I doubt if it will result in wide spread conversion of the sites back to the original grasslands.

- 5) To evaluate the effect on the individual plants, select 25 plants for each treatment of each species. The treatments would be no cut, cut only, cut plus burn, cut plus browsed, cut plus browsed plus burn. To accomplish the unbrowsed treatments acacia stems could be placed over the cut stumps. This would then not require different plots but just measurement of the individual plants.

**Task E. Review of SCF/US's DAP pasture improvement activity for impact on the environment as well as human and livestock populations.**

In general the impact of the pasture improvement activity on the environment is positive. The pilot resulted in an increase in the hydrologic stability of the site and a movement of the plant community back towards the original grasslands that once dominated the site. Based on the increased diversity of habitat types this provides, biodiversity should also increase in the area. Increasing the grasslands will also improve the forage base for the existing livestock in the area. This will improve the milk and meat production in the area and further improve the nutritional status of the human population in the area. However, because of the changes in the grazing practices there is little chance to increase the number of livestock in the area at least in the near future. The second program working on contraception to reduce the human population appears to be the key to longterm sustainability in the system. For a detailed description of this objective see Appendix A.

**Task F. Recommendations**

1. After reviewing the current pilot I would follow the recommendations suggested by Alemu (2000). It would improve long term sustainability and reduce the fluctuations of the current system. For the local community the primary changes are the current grazing practices. To maintain the grassland using fire, livestock deferment would have to occur on a regular basis. This will allow enough fuel to accumulate for fire to be used (Figure 1). The elders we talked to indicate that they used fire in the past on a 2-3 year cycle. While the area may not need to be burned this frequently, further evaluation would be needed to determine the exact required fire return interval. With the current information, I would recommend a fire return interval of 3-5 years. The time would be determined based on the climatic conditions and evidence of shrub seedling establishment. The first two burns may have to be spaced very close together. Some of the shrub species have seeds that are stimulated following fire. To keep them from establishing, a quick fire return interval would be

advisable as soon as seedlings are noticed. The people around Mi'essa did alter their grazing to build fuel on the demonstration area, I think this provides evidence that the communities are ready to accommodate the needed grazing treatments to meet the ecological needs of the plant communities.

2. Maintaining the longterm health and productivity of the rangelands would be enhance, if more groundcover were maintained on all sites. Currently the hydrological stability of all the sites visited is low. There is evidence of significant amounts of sheet and rill erosion on all sites. But my observations are based on a one time visit, which is at the end of the third year of a drought. This obviously has dramatically reduced the normal ground cover. Oba (1998) reports soil stability to be adequate at the time just prior to the current drought.

On the grassland and *Terminila* sites reintroduction of fire and management of the livestock would reduce this problem. On the other sites there may have to be a reduction in livestock numbers to improve ground cover. Current situations seem to make this impractical though there has been a dramatic loss of livestock in these particular communities. Small-scale manipulations that could be strategically placed and managed could help minimize the adverse impacts of sediment movement into ponds. This could be done just upslope from ponds where grass cover would help trap sediment before it reaches the pond. (See recommendation 3)

3. Restoration work should be done in conjunction with pond development and desiltation. Where SCF/US did the grassland restoration in the Mi'essa area it was immediately upstream from a pond development. The community has implemented the recommendations and all of them are currently working. The bush reduction and altered management has improved the hydrologic condition of the immediate watershed even during the current drought. This should provide a longer life expectancy to the ponds, because of decreased sediment loss on the hillslopes. This requires significant coordination, which is currently working on the site at Mi'essa. The improved management has increased ground cover and the buffer strips developed around one pond this year shows the area is capable of producing over 2000kg/ha of forage even during dry years. The livestock management of the area should be done to rotate the animals every year. Each area should be rested during the stem elongation phases of growth at least once every three years. This will help maintain the long-term sustainability of the system.
4. The elders understood the importance of maintaining the grassland once it was developed but educational programs would have to be used to ensure the elders and rest of the community are together on how to accomplish the changes in management. Research with acacia shows a 57 % increase in grass biomass when the trees are removed (cited in Coppock 1994). The increased grass production that would result from the reduction of the bush and rotation of the

animals should allow for the same number of animals to be maintained. On the *Terminalia* sites production could improve enough, to help build additional drought reserves. If the community does not agree to alter the grazing practices to allow fire to be reintroduced at a regular interval then there is little for long-term sustainability of maintaining these areas as grasslands.

5. Discussions with the elders indicate part of the problem is that no one has responsibility for the land. This was originally the role of the Abba Dheda (father of the range). There must be some commitment for the longterm success of the project from both the community involved and government officials that enforce local control. The current process SCF/US has implemented where the community is involved first in identifying the problem as well as developing the solution is a great step forward. I would also recommend the continued involvement of SCF/US in the natural resource committee involving the Ministry of Agriculture, GTZ and others. This group is working to help build the strength of the local communities to empower them to be locally responsible. This would ensure the local community benefits from their future efforts. Oda (1998a) described some of the frustrations about others moving into reserved areas managed by one community. When they complained, the local GO (PA chairman) not only supported the outside community, but also was part of the group moving livestock on to the reserved forage. If this is allowed in the future, it will undermine any potential for longterm management changes. All the GO's and NGO's in Negelle recognize this. They appear to be trying to develop a coordinate strategy to help the local people use their knowledge, which will benefit themselves as well as the environment.

Currently fire could be easily reintroduced into these areas because of the historical use, knowledge and leadership of local elders. However, if the use of fire is not reintroduced into these areas soon, the potential for the local people to use this technique will be dramatically reduced. The younger generation has not been exposed to the practice of using fire for the last 25 years. Their ability to integrate and use an unfamiliar technique will be reduced. This will have both ecological as well as safety consequences.

6. I would recommend training for the local SCF staff on plant-herbivore interactions and prescribed burning. The most important would be the plant herbivore interaction training because of its application to the local area. This course deals with the new theories and their application on animal behavior and learning which can be used to direct vegetation changes. Currently Dr. Fred Provenza teaches a two week short course in July at Utah State University in Logan, Utah. I currently teach a one week rangeland fire ecology and prescribed fire course in the spring. A second part of the training would be to provide basic training on rangeland ecology for local staff in Ethiopia. This course or series of courses would be developed for the local environment of the Borean Plateau region. This course should include the

basics of vegetation manipulation on rangelands, fire ecology of grasslands, plant animal interactions and grazing management. There are several people that may be able to provide the training. Layne Coppock, Solomon Desta are two that should be consulted because of their longterm work in the area.

#### **Task G. Seminar.**

An introductory seminar on rangeland ecology was conducted at the SCF/US office in Negelle, Liben, Ethiopia for the local staff and other local NGO's and GO's.

Specific topics covered during this workshop were:

- A) Manipulation of rangeland plant communities.
- B) Rangeland Fire Ecology.
- C) Prescribed Burning on Rangelands.
- D) The effect of range vegetation on hydrologic stability.
- E) Discussion on appropriate policies to enhance rangeland sustainability.

## Appendix A.

### Assessment of the ecological status and origins of the different bush types on the grazing lands of Liben Woreda, Borana.

#### Original Conditions

The Liben Woreda was originally dominated by grassland savannahs (over 70%) according to local elders in current interviews (SCF 2000b). This is also supported from additional interviews and work done by Eco-consult (1997) and Oba (1998a). Coppock (1994) has also found a tremendous reduction on the original grassland savannahs in the region. The Liben Woreda had no grasslands listed in the vegetation map developed by Eco-consult (1997, page 7). In the Mi'essa we found an area on the vertisol soils representing less than 2% of the district that can still be classified as grassland. However, even on these sites bush has established and the area is in the process of shifting away from a grassland. The grasslands have been reduced to such a point they could not be mapped at the current scale used in the report. This area originally had no bush and was locally referred to as "area with no cattle pens" because there was not enough bush found to construct any pens (Eco-consult 1997). The change represents a reduction of the grassland ecosystem in the area by more than 95%.

Interviews with local elders and the literature indicate the traditional wet season grazing areas were originally grassland savannahs, which had "grass as high as a man". These conditions started changing between 25-35 years ago according to those interviewed and are corroborated with the literature. The cause of the change has been listed as the alteration of the grazing practices, overgrazing, increased human populations and the removal of fire starting in 1974-1976. The current conditions are well described in Eco-consult (1997), Coppock (1994) and SCF (2000b).

The original grasslands were maintained because of an active disturbance pattern that minimized the competitive advantage of the shrubs and maximized the competitive advantage of the grasses. As this set of disturbance patterns changed, the plant communities are adjusting to the current set of disturbances (Figure 1.) If the original grassland savannahs are to be restored, then the current disturbance patterns must be altered and reestablished to favor the grasses. This can be done in several ways, depending on the local circumstances.

#### Current situation

The *Acacia* and *Sericocomopsis* plant communities have sufficient shrub cover to minimize raindrop impact. However, ground cover is reduced to the point overland flow and sheet erosion is causing significant soil movement at this point in time. These communities have relatively few perennial herbaceous species. This suggests that



without major changes in management, little can be done to change the hydrologic stability. These communities moved from a grassland community to a bush community very quickly, less than 30 years based on local experience. This indicates they have a low resiliency (plasticity) as a grassland, but because of the reproductive strategy of the shrubs, these bush communities have a very high resiliency (Archer and Smeins 1991, Figure 1). Oba (1998) found these communities have greater than 2000 bushes/ha. Much higher than what is defined as a grassland savanna. This situation is best described by Figure 2a and b. These communities have moved completely from the grassland phase to a bush phase. The effort needed to first move the plant community back to a grassland, then maintain the grassland will be significant.

Figure 1. Estimated location and changes in plant communities as they move from grasslands to bush dominated communities. Adapted from Archer and Smeins 1991.

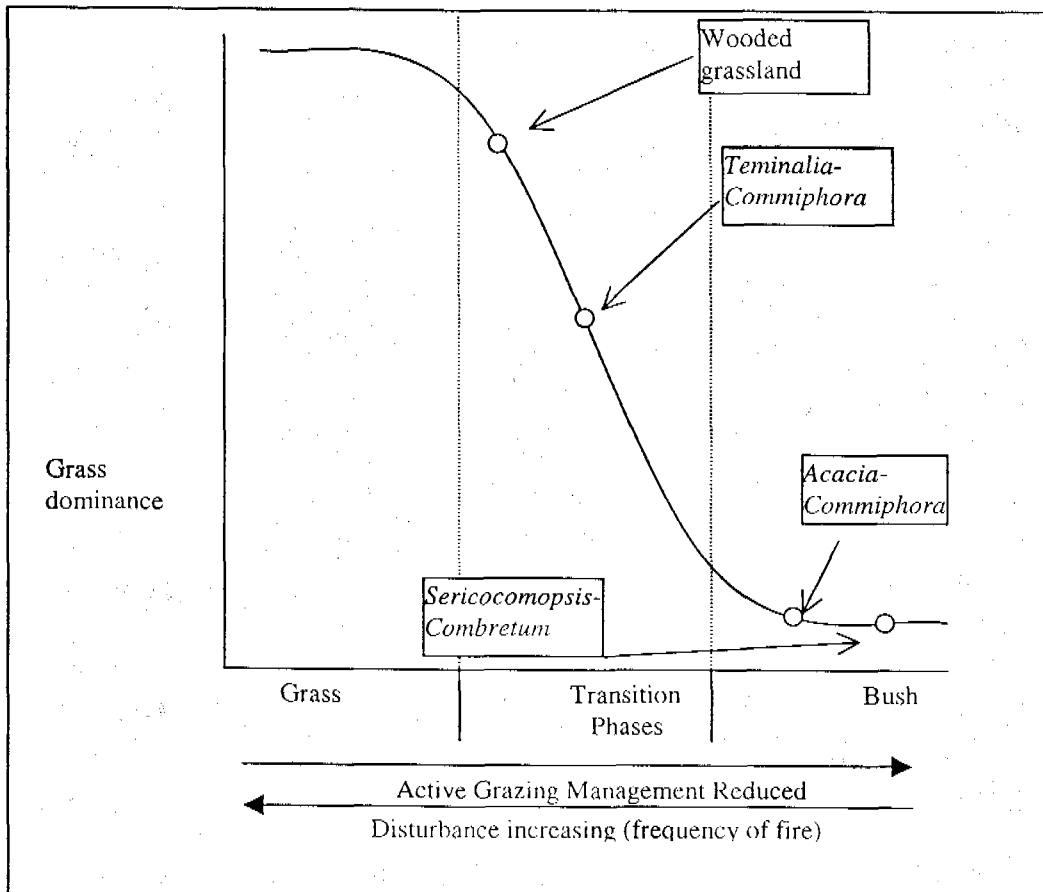
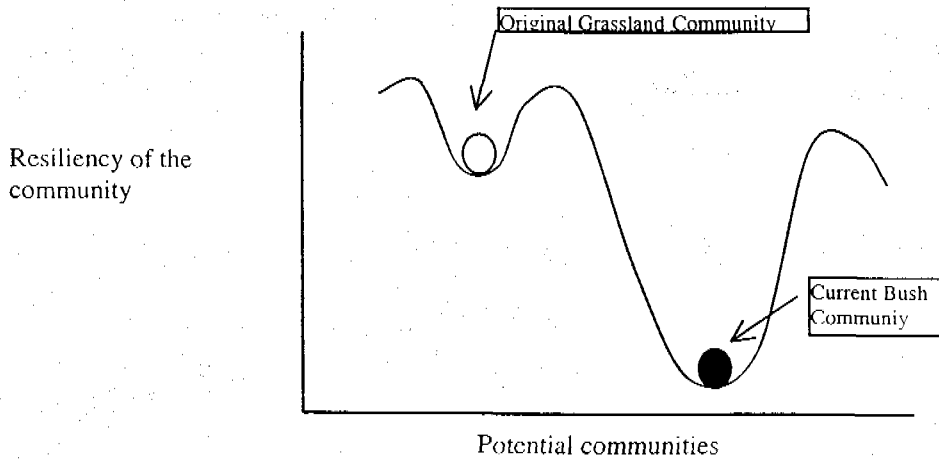
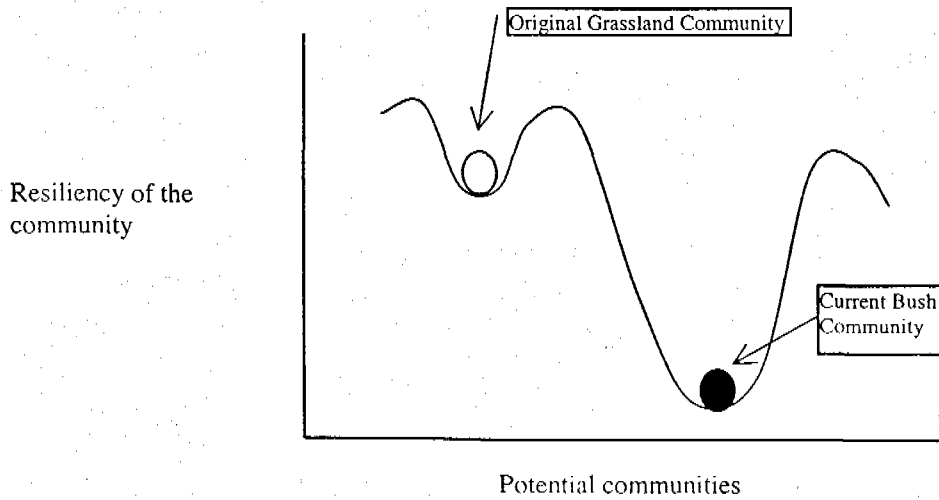


Figure 2. The representation of the different plant communities resiliency based on their estimated original conditions  $\circ$  and current conditions  $\bullet$ , as represented by the ball and trough theory as adapted from Krebs 1985.

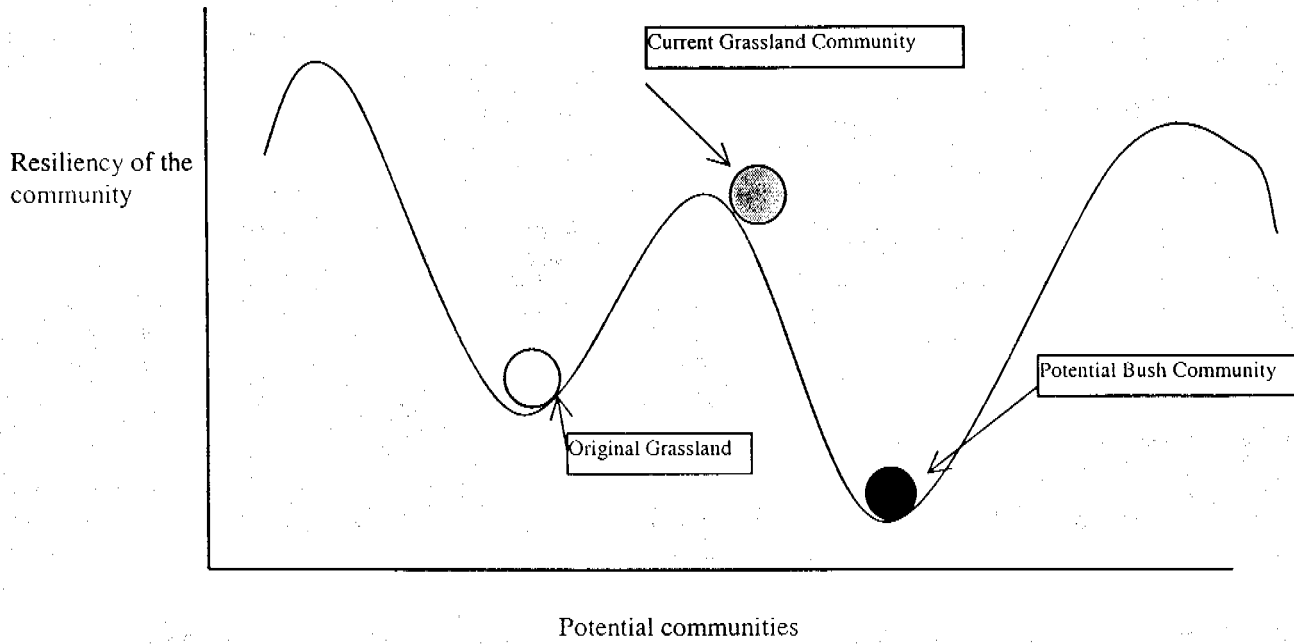
A. Estimated locations of the current and original grassland communities on the *Acacia-Commiphora* plant community.



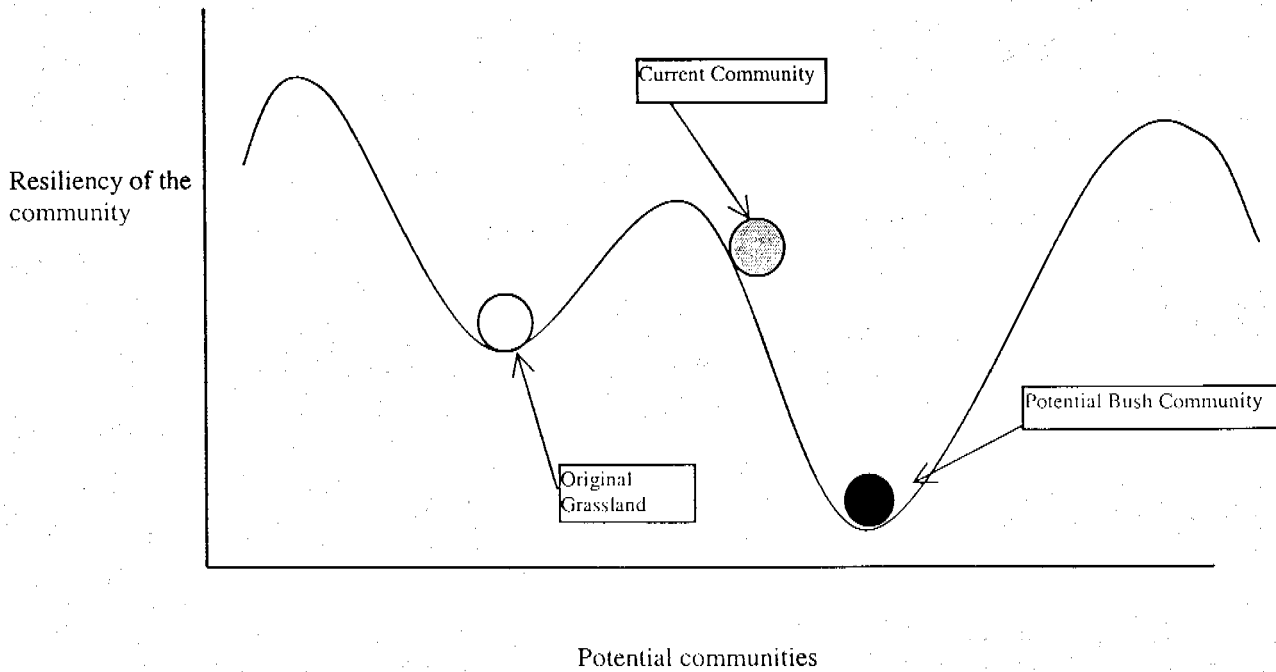
B. Estimated locations of the current, and original potential communities on the *Sericocomopsis-Combretum* plant community sites



C. Estimated locations of the current, original communities and potential communities on the wooded grassland sites.



D. Estimated community resiliency of current, original and future potential communities on the *Terminalia-Commiphora* sites.



On the wooded grassland and *Terminalia-Commiphora* sites, ecological conditions have not moved far from the original grasslands on these soils (Figure 1, and Figure 2c and d). The wooded grassland sites have the greatest potential to restore and maintain the original grasslands. There has been a significant establishment of *Acacia drepanolobium* (average >420 bushes/ha, range 202-870 bushes/ha) Alemu (2000). In a study by Oba (1998a), he found the stand structure to only represent newly established plants with none in the mature age class (greater than 8 cm gbd) of *A. drepanolobium* in the Liben Woreda. The effort and management changes needed to restore these areas and maintain them will be relatively small (Figure 2c). *Acacia seyal* abundance has also increased on these sites. If nothing is done on these sites, they will continue to move towards a bush community. In addition, work cited in Coppock (1994) shows acacias in this area can reduce grass forage production by over 55%. The reduction of the shrubs would help increase the forage availability in the area.

Now that the bush has established there is little chance the traditional disturbances (altered grazing pressure or just adding fire by itself) will move the system back to the original states on any of these sites. These ideas are commonly referred to as the state and transition model (Friedel 1991, Laycock 1991) as well as Oba's (1998a) discussion. The people living in the *Acacia* and *Sericocomopsis* areas have already shifted their animal herds to contain more browsers (goats and camels) to accommodate increase in the shrubs and reduction of herbaceous vegetation. Unpalatable shrubs are increasing in this area that may cause future problems if management does not adjust to them.

All sites visited show problems with the hydrologic stability of the sites. The current condition indicates an accelerated erosion rate of the topsoil, which will reduce productivity in the future. It should be noted that I visited this area at the end of the third year of a drought. Alteration of the grazing practices would have the greatest impact on improving hydrologic stability on all sites in the area. On the wooded grassland sites, there is still sufficient grass cover that small changes can significantly alter the hydrologic conditions of the rangeland systems to minimize soil erosion. Oba (1998) found no problems with hydrologic stability before the drought.

The density of the bush in the *Acacia* and *Sericocomopsis* communities makes it unlikely that alterations would provide significant changes in the current situation. The SCF/US has also come to this conclusion and focused their efforts on the wooded grassland. The costs of hand cutting the bush, make it unlikely that it could be cost effective in the future if it has to be done on a regular basis. The one time investment of hand cutting followed by a cheaper disturbance such as fire would likely meet the economic needs of the community. For fire to be reintroduced the livestock grazing practices will have to be altered to allow the grasses to establish and fuel loads to build sufficiently. The community would have to make the longterm commitment to alter the livestock grazing management to maintain the restored project (add back in the disturbance). All of the elders we talked to, recognize the situation and understood that fire would have to be used continuously for the projects to be sustainable. They were

willing to alter their total management of the system to work the disturbance of fire back into the wooded grasslands.

After reviewing the areas I would suggest the effort be directed to the sites, which have the greatest potential to be reestablished as grasslands (wooded grasslands and *Terminalia-Commiphora* sites) (Figure 2). These sites must have the commitment of the local communities to reintroduce fire as a disturbance if it will be sustainable.

The SCF/US staff has done an outstanding job of working with community elders in several areas. First to understand their commitment to making changes, then to work with them to know what they can do, and finally to help them understand what they need to strengthen locally to implement a change.

**Appendix B. Assessment of the ecological and social impacts, and recommendations to improve the implementation of the pilot study used by SCF in Liben Woreda, Borana.**

Total removal of the shrubs was not done on any of the sites. All sites left 20-50 larger shrubs/ha to reestablish the savannah. The removal of the bush is focused on *Acacia drepanolobium* and *Acacia seyal*. The other species are cut to a density that represents a grassland savannah and what the local communities feel are appropriate for shade and other needs. No species were totally removed from the system to address both the concerns dealing with biodiversity as well as the practicality that eradication is not feasible. A second aspect of leaving some of the trees for shade is they can also increase the amount of grass biomass produced. The amount of bush cover that is found beneficial depends on the soil type and depth, and bush species (Scifres et al. 1982, Rasmussen 1986). No studies were found in Ethiopia that documented this, but here are antidotal references in Coppock (1994). Other species of bush have numerous additional values as well. However, studies on competition between grass and the acacias also show a tremendous reduction in grass production (57%) (Coppock 1994).

Mr. Alemu developed a study instead of a pilot, which can provide statistical power to support his recommendations. It was impressive to see the study design developed. I commend Mr. Alemu and SCF/US for providing such a professional approach to uncertainty. He not only looked at the suggested scenarios, he also added a treatment, based on his own review of the existing information (Alemu 2000). I think the recommendations he has developed are appropriate for the wooded grasslands and could work in the *Terminalia-Commiphora* community. These areas still have sufficient perennial grass plant cover to take advantage of the released competition after reduction of the bush cover.

The recommendation developed by Mr. Alemu is to cut the trees off at a height of 50 cm during the dry season, leaving the bush material on the ground. Then cut off the sprouts the next dry season followed a prescribed burning the following dry season. This technique was very successful in reestablishing the grassland savannah appearance of the sites. However, there are still over 100 plants/ha on the site that were only suppressed by the current treatment. If fire as a disturbance is not maintained on a regular basis the bush will re-dominate the site relatively quickly (less than 10 years).

This recommendation does not agree with the report by Jemal and Menzel (1997). They think that the wood should not be wasted in prescribed burns but should be transformed into charcoal. While their recommendation has merit, this may not work in all areas. Under the current management, the downed wood provides two ecological functions. The first is to protect the grass plants from herbivory, allowing the plants to improve their reproductive capabilities and vigor. The second is the increased fuel load

provided by the protection will improve the fuel continuity and ensure an adequate prescribed burn. Jemal and Menzel (1997) admitted their prescribed burns were not successful because no deferment occurred following the removal of the trees. This was also apparent on the SCF/US site where the cut trees had been removed by the military for firewood. The third reason is the local people do not seem to have the desire or current transportation system in place to convert the wood to charcoal.

The ecological advantages could be minimized if livestock were always excluded from the treatment areas. This also seems difficult giving the current situations. I would suspect that after a significant area is cleared and the forage production is developed the pastoralists, will be more willing to adjust their management on future sites. Education could help overcome all three of these disadvantages. It seems unrealistic to provide the training to change these attitudes and beliefs until the local people see the positive potential of the changes. Just telling people that it will get better rarely works. The current pilot has started this process to change their attitudes. This will allow these communities the opportunity to either develop charcoal production capabilities or use the wood as firewood in the local area as an alternative in the future.

On these areas where the initial cuts are started, I would provide the following adjustments dealing with the fire prescriptions to the treatment recommendation: (These recommendations are developed from my experience and research with grassland fire prescriptions and discussions with the local elders. The inclusion of the information from the elders should enhance the acceptance of the recommendation). Mr. Alemu has already done a very good job involving the elders and working with the communities to ensure the pilot was successful. These recommended prescribed fire prescriptions recommendations are more conservative than what the elders and the literature described. The reason for the more conservative prescription is to make sure the mature plants left on the site, is not damaged by the fires. They should be maintained as a single stem growth form. A hotter fire prescription could topkill these plants resulting in more multi-stemmed plants causing problems moving people and animals through the area.

#### Fire prescription

Burn approximately one month before the long wet season (Ganna).

Do not graze until after the plants have reached a minimum height of 30 cm.

Desired fuel loads greater than 2500 kg/ha.

Create the fire breaks 6-8 m wide. Established prior to the day of the main headfire. I would recommend the following weather conditions. For the fire breaks.

Temperatures less than 18 C (65 F) preferably less than 15 C (60 F).

Winds less than 8 km/h (5 mph)  
RH 40-60%

#### Main fire weather conditions

Temperatures less than 27 C (80 F).

Wind 8016 km/h (5-10 mph).

RH 30-50 percent.

You could use the higher end of the humidity if you have a greater fuel load. 20% has been recommended but I would use these with caution. (I would also recommend SCF purchase a belt weather kit. This will allow the weather conditions to be determined on the site. Kit must include a wind meter, and sling psychrometer.)

Ignite the fire after 3:00 pm.

To improve the safety I would also recommend the use of a backfire on the downwind side, followed by the ignition of the head fire.

An additional method to improve the safety of the prescribed fire is to have livestock graze the parameter of the burn area. If the fine fuel loads are less than 500 kg/ha for 100 m down wind, the chances of fire escapes are minimized. Care must be used to not allow the animals to graze the treated areas.

Prescribed burns should be repeated on about a three to four year cycle to keep shrub seedlings from reestablishing and erasing the gains from the hand cutting.

These recommendations would work for the Wooded grasslands and *Terminalia-Commiphora* communities. The *Acacia-Commiphora* and *Sericocomopsis-Combretum* communities do not have the characteristics that would allow this type of restoration to work on a sustainable basis ecologically. The later two community types have been transformed from a grassland to a shrubland since the cessation of fire approximately 25-35 years ago (Figure 1). Discussions with the elders indicate stopping fire (25 years ago) may not have been the only cause. Human populations (and subsequent livestock numbers) also were increasing which could have started reducing fuel loads enough to reduce the effectiveness of fires during the previous 5-10 years prior to the fire ban.



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## Jidola and Gannale PAs

Shrubs started increasing about 25 years ago. Grass was tall (above knee's). They would start the fires about 1 month before the long wet season (Ganna). They would not start the fires earlier because the winds were too strong. The wind was out of the north. They would not use a strong wind because the fire would jump 3 m (less than 10). They would start the fires after 3 pm because they did not want to burn the neighbors up. They would also coordinate with the neighbors so everyone knew what was going on and where the stock were. The fires would go about 10-15 km. They would start the fires in the afternoon when the ticks had moved up on the grass. This would ensure that they would be killed. If burned before that, the ticks were not reduced. The grass would green up before the wet season indicated that there was going to be lots of rain. They would burn every other year. The margin of the current year's burn was the boundary last year's burn. This made it easy to control since there was less fuel because the animals were grazing the area preferentially compared to the unburned area.

## Kobadi PA (Elder Kadir Godana 62)

They would burn about one month before the Ganna. Any earlier was not advisable because the winds were too high. Just wanted the grass to shake. If it was very hot they would wait for the sun to incline and cool off before they would light the fire. They would light in the afternoon. This allowed them to wait for the sun to incline if necessary. It also ensured everyone was around to help put the fire out if needed. They would burn when they would see just a few small tillers on the grass plants (less than 3 cm). If the grass greened up after the burn then they new rains would come.

Prior to the grass drying out completely they would establish fire breaks around their encampment. The elders would be the ones who determined when an area should be burned. If the grass was too old and dry it was time to burn. Indicating there was sufficient fuel to reduce production.

## Mi'essa - (Elder Ibrahim Qurie 82)

They would start fires about one month before the Ganna. If they burned earlier the grasses would die. They would key off the new tiller on the grass. When there were new tillers less than 3 cm. If there were no tillers on the grass they would not burn that year. They would not graze the area until two months after the Ganna started. They would use the winds that would keep

the grass shaking but not laying down. For small burns, they would start in the morning because they were easy to control. For middle sized burns they would start in the mid-afternoon. Big burns more than 20 km, they would start at noon. There was dew on the grass in the morning so you would not have to if dry out before things would work well.

The Abba Hadim would make the decision when to burn and when to put animals back on the site. They had lots of country and fewer people so things were much easier.

His views on the local ecology. On the clay soils the *A. drepalobium* always occurred the Cattle brought the acacia from the dry season areas which always had many shrubs. White acacia started on the black clay soils then moved to the red clay soils about 35 years ago. Cause was the overgrazing of cattle. The fires used to control the seedlings, however, with overgrazing the burns were not as effective. This allowed the shrubs to establish and start dominating. The grass at the time of the burns was rank and no good. The fire would refresh the grass and kill the shrub seedlings. They would burn about every 3 years.

Hadhessa PA Elders Nura Yabicho (66), and Tadacha Kana (62)

Shrubs showed up and discussed first in the Gada Guyo Boru - 40-48 years ago. High densities of brush discussed in the Gada Jilo Aga -24-32 years ago. Before grass was as high as a your head (and he had tall head 6'8"). They would burn vast areas 15-20 km. The brush increased for three reasons. 1) shrubs established and built up the seeds, 2) camel, goats and sheep brought it in with their dung; 3) the roots were very strong. Cattle only brought grass.

They would burn about a month before the Ganna. They burned to remove the rank growth and allow the fresh growth to increase. It would also kill brush. The fire would kill the little ones, but larger trees would escape.

They would light the fires in the afternoon after everyone was done with their chores. This would make sure everyone was outside to help put the fire out if needed or restart it if needed. Indicates how spotty the fuel was in some areas. They would start the head fire by using one point if fuels were heavy. When fuels were light they would light a spot about every 20 steps. The size of the head fire ignition was based on what they wanted to do.

Winds grass shaking, sunny no clouds. If cloudy not enough wind. Burned during this time of year because moisture in the air would have the grass green up before the rains. Grass on the clay soils would green up before the rains, if the air was moist. Grass on the lighter soils would not green up until the rains came.



# ILCA SYSTEMS STUDY

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## The Borana Plateau of Southern Ethiopia:

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**Synthesis of pastoral research,  
development and change,  
1980–91**

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by

D. Layne Coppock

1994

### 7.3.1.4 Site reclamation

As the last stage in the range management hierarchy, reclamation of degraded sites is the most intensive and expensive management activity per unit area (Pratt and Gwynne, 1977: p 122). Because of this, site reclamation may initially appear as an unsuitable activity for communal pastoral systems. Recent experience on the Borana Plateau suggests, however, that when a confined pastoral society is under increasing pressure to secure adequate grazing resources, it may be easier to achieve a consensus on actions to rehabilitate land compared to those intended to slow degradation of land; the latter appears, at least superficially, to be inadequate. From surveys it is apparent that the Boran are interested in participating with SORDU to reclaim sites, but feel that there has been insufficient dialogue to date (Solomon Dessalegn, TLDP/ILCA postgraduate researcher, unpublished data). It is anticipated that effective participation within the community by development agents could achieve a satisfactory level of site-specific control as long as the local community agrees that action is warranted. While some strong leaders in Borana society may help implement local programmes to change several aspects of resource use (Hodgson, 1990), many others require the assistance of outside authorities (Solomon Dessalegn, TLDP/ILCA postgraduate researcher, unpublished data).

### Herbaceous layer

Pratt and Gwynne (1977: pp 121–126) reviewed aspects of reseeding degraded land, and only some species useful for reclamation will be noted here. It must be emphasised that given a nucleus of good perennial grasses, it is easiest to achieve recla-

mation by bush-fencing or declaring areas off limit by the Boran to permit natural recovery. Some form of protection must be implemented in any case, and if this cannot be done, no amount of seeding will make a difference. According to the proposed model of cattle population dynamics in relation to drought (see Section 7.2.3: *Anticipated short-term cycles*), it is most likely that successful site rehabilitation will occur during the drought-recovery phase when cattle densities and demand on forage are lower. Pratt and Gwynne recommend East African perennial grasses for reseeding sites and these include some prominent local species such as *C. ciliaris*, *C. roxburghiana*, *C. dactylon* and *Enteropogon macrostachyus*. Tables A6 to A10, Annex A, give environmental guidelines for some of these species. If in doubt, inspection of similar sites can provide additional information. A discussion of reseeding procedures is provided in Pratt and Gwynne (1977: pp 123–126).

It is envisioned that priority sites for reclamation of the herbaceous layer include those in the upper semi-arid and subhumid zones that are rapidly degrading due to pressure from increasingly sedentary pastoralists (Section 3.4.2: *Environmental change*). These sites have higher rainfall and cooler temperatures than the rest of the plateau, and thus offer better possibilities for success although not for exotics like *S. hamata* cv Verano because of the cooler temperatures (Section 7.3.1.3: *Forage improvements*). One disadvantage, however, is that these regions to the north (not served by wells) occur outside of the traditional *madda* system and have been in the domain of PA organisational structures. This may require a different approach in terms of getting support from the local people. In addition, the trekking routes through this area that are used to move cattle up-country (Assefa Eshete et al, 1987) present other social challenges for implementation.

#### **Bush control: Field methods and policies**

Bush encroachment has occurred on the Borana Plateau over many years and may be exacerbated by the grazing impacts of cattle (Section 3.4.2: *Environmental change*). If this hypothesis is correct, increases in cattle density should aggravate bush encroachment under suitable rainfall conditions. Bush establishment thus may be most likely to occur as an episodic phenomenon during prolonged periods in the high-density phase of cattle population. Although bush encroachment can limit using land for cattle grazing, it may serve a useful purpose in site protection and rehabilitation (Section 3.3.2: *Long-term vegetation change*). Bush control programmes must thus be tempered by this consideration.

**Prescribed burning:** Woody plants may be variously controlled using manual labour, chemicals, prescribed burning, machinery and browsing livestock. Pratt and Gwynne (1977: pp 128–138) provided a review of experiences from East Africa. Although it is acknowledged that fire has variable effects on controlling woody vegetation and more research is needed, it is still the most cost-effective means for bush control in East Africa (Pratt and Gwynne, 1977: p 132).

Solomon Dessalegn (nd) used prescribed burning to assess impact on an acacia community at Wollenso Ranch during the warm dry season of 1989 (Table G10, Annex G). These data indicate that overall mortality rates of trees on two sites were about 30%. Younger trees (<2 m tall) suffered mortalities of 35% while larger specimens lost only 11% of their numbers. The finding that younger age classes are more susceptible to fire has been reported elsewhere (Norton-Griffiths, 1979; Pellew, 1983; à Tchic and Gakahu, 1989). The protection afforded older trees may be due to increased trunk thickness (which protects vascular tissues), elevation of buds and foliage and whether accumulation of sufficient herbaceous fuel load in the understory is inhibited by shading and/or root competition. Fire is thus **only** a partial management solution in that it mostly inhibits recruitment of young trees but it still can gradually shift the advantage to grasses. Older trees survive fires to produce seed for the future, however. It is important to note that fire has variable effects related to site and species. For example, it may stimulate germination in some woody species that are adapted to respond positively to burning (e.g. *A. brevispica*). Adult trees less than 2 m tall may be destroyed by one fire. A large stand of *Commiphora* sp was completely killed by a wild fire at Dembel Wachu Ranch in 1987 (D. L. Coppock, ILCA, personal observation). Effects of site and species on the susceptibility of trees to fire are reviewed in Pratt and Gwynne (1977: pp 128–138).

Solomon Dessalegn (nd) interviewed leaders of five Pastoral Associations (PAs) in 1989 and found that the Boran used to burn sites once every three years to kill bush, control ticks and improve the nutritional quality and accessibility of grasses. These benefits from burning are well known elsewhere (Hobbs and Spowart, 1984; Coppock and Detling, 1986; Mbui and Stuth, 1986). In the view of the Boran, cattle grazing and absence of fires were mostly responsible for bush encroachment. Government policy restricting range fires was considered by these leaders as a major management constraint. Reserving sites for burning, however, was reportedly more difficult than in the past because of forage demand from a large cattle

population (Section 3.2.5.2: *Household use of plants and pastoral perceptions of range trend*).

A sound range-management programme based on prescribed burning requires years of detailed site-specific research (Pratt and Gwynne, 1977: pp 128–138). This may be a luxury, however, that few national programmes like SORDU can afford. It is noteworthy that the policy prohibiting burning on the Borana Plateau was lifted in 1990 (Tafesse Mesfin, TLDP General Manager, personal communication) because of the perception by local administrators that bush encroachment was a significant threat to the production system. It is expected that the Boran will now be able to recommend sites for burning and SORDU will provide regulation through site evaluation, approval of methods and by helping organise the work (Kidane Wolde Yohannes, TLDP range ecologist, personal communication). The Boran have indicated that they would work with SORDU on bush control (Coppock et al, 1990: pp 21–22). Pratt (1987a: p 22) recommended that with the ban lifted, controlled burning should be allowed in the semi-arid and arid zones where appropriate, but not allowed in upper semi-arid and subhumid zones that are more in need of rehabilitation of the herbaceous layer (see Section 3.4.2: *Environmental change*).

Without regulation, the danger is that sites may be burned too frequently under today's conditions of higher human and livestock populations. The tendency may be to burn more for short-term gains such as stimulating green flush. Effects of burning on improving forage quality are only short-lived (McGinty et al, 1983; Mbui and Stuth, 1986) and more frequent burning can damage microbes in the topsoil (Biederbeck et al, 1980), expose soil to erosion (Ali et al, 1986) and kill important forages such as *Chloris roxburghiana* (Pratt et al, 1966). In contrast, appropriate burning may stimulate increases in *Themeda triandra* (Pratt and Gwynne, 1977: p 246). This species is an important forage in the north-central part of the Plateau and it has been noted to be in decline possibly as a result, in part, of the absence of fire (Menwyelet Atsedu, 1990: p 83).

Optimal burning frequencies are thus anticipated. Pratt and Gwynne (1977: p 133) noted that a burning interval of three to six years checks most bush encroachment in relatively open areas. Burning experiments with thick bush based on an initial series of annual and biannual fires are also proposed in Pratt (1987a: p 23). If careful records are maintained and site monitoring is carried out, it may be wise to use sites nominated by the Boran as part of a comprehensive research and management programme. One other danger of loosely regulated burning is the threat it may pose to juveniles of useful tree species. For example,

Pellew (1983) and á Tchic and Gakahu (1989) noted that younger age classes of *A. tortilis* are vulnerable to fire.

The likelihood that higher populations of livestock may reduce the capability to implement burning programmes is a significant constraint, but this will vary among *madda*. Consideration of the cattle population cycle in response to drought (see Section 7.2.3: *Anticipated short-term cycles*) may be useful in evaluating opportunities for burning. Early in the drought-recovery phase cattle populations would be lower and forage (fuel load) more abundant. A lighter grazing pressure could also encourage more grass growth that could further keep tree seedlings from emerging after fire. It is stipulated that if burning can be focused to occur in this time frame implementation could be more successful. It may also be expected, however, that the pastoralists will be most interested in burning during the high-density phase, largely for short-term goals of improving cattle nutrition or controlling ticks.

**Mechanical and chemical methods:** Focusing on *Acacia drepanolobium*, Solomon Dessalegn (nd) conducted an experiment that included various treatments of manual cutting (stumping), ring-barking and application of used motor oil or TORDON 101 arboricide to stumps. Subsequent mortality rates are shown in Table G11, Annex G. It is apparent that without the use of arboricide, other forms of control were largely ineffective. In addition, *A. drepanolobium* resprouted easily from stumps not treated with the arboricide, which results in a bushier growth form that is more likely to be obstructive to livestock (Plate 7.4). The ability to regenerate after simple cutting is common among East African trees (Pratt and Gwynne, 1977: pp 133–134). Although the use of an imported chemical may be regarded as inappropriate, it certainly was the most cost-effective means of ensuring kills in this trial. It has been calculated (Coppock et al, 1990: p 24) that with only 1 ml of arboricide/stump, the cost to kill 600 trees/hectare is less than EB 10 which is a small addition to the cost of labour that is otherwise much less effective. One other drawback with chemicals, however, is that their safe use requires careful supervision. Attempts to control bush purely through human labour are thus thought to be expensive, time consuming and largely ineffective. Not surprisingly, the Boran do not express much interest in engaging in such activities unless they are paid or receive Food-for-Work (D. L. Coppock, ILCA, personal observation). The lack of interest in labour-intensive methods for bush clearing among the Boran may reflect time constraints as well as the labile land tenure; i.e. if a location becomes unusable because of bush encroachment, the people can probably still move

Plate 7.4. A specimen of *Acacia drepanolobium* a few months after an attempt to kill it by stumping using manual labour.



Photograph: Shewangizaw Bekele

elsewhere. Options to move are probably declining, however, and this may stimulate interest in bush control among the Boran.

**Wood collection:** Billé and Assefa Eshete (1983b) noted that while the general effect of pastoralists on trees through wood collection may be locally significant around individual encampments, this is not important for bush control in a regional context. This agrees with the interviews of pastoral leaders by Solomon Dessalegn (nd) in which they indicated that routine harvest of wood for cooking and

construction has little effect on tree populations overall (Coppock et al, 1990: p 21).

**Charcoal production:** Charcoal production from undesirable woody plants is a cost-effective means of bush clearing (Pratt and Gwynne, 1977: p 129; Cossins and Upton, 1988b). Solomon Dessalegn (nd) conducted initial trials using local methods to assess whether some of the encroaching species could be turned into suitable charcoal. There was concern that abundant and apparently useless species such as *A. drepanolobium* may not make suitable charcoal because of their slender trunks, commonly less than 20 cm in circumference. It was found that the dry-matter yield of charcoal from a standard fresh weight of 350 kg ranged from 16 to 25% for five species (Table 7.7). A good predictor for efficiency of charcoal conversion was per cent moisture of wood (Coppock et al, 1990: p 24). As per cent moisture increased ( $x$ ) so did the per cent charcoal yield ( $y$ ) in a significant correlation ( $y=0.715x - 38.6$ ;  $r^2=0.40$ ,  $P=0.003$ ,  $N=20$ ). Samples of charcoal were taken to Addis Ababa to see if traders could evaluate the quality (Coppock et al, 1990: p 27). There were no repeatable differences among rankings of samples by five traders; so all were judged as similar. The traders, however, regarded acacia charcoal as superior to the non-acacia charcoal that dominates the Addis Ababa market. The lump size was considered adequate and the dull matte finish suggested a good combustibility and absence of sparking (Coppock et al, 1990: p 27).

A cost-benefit study suggested that 9400 kg of charcoal from 600 *A. drepanolobium* trees/ha could provide a gross return of over EB 7400 if marketed in Addis Ababa (Coppock et al, 1990: p 27). The total cost for 135 man-days of labour, local transport, field supplies and arboricides was estimated as EB 1125/ha. The net profit was on the order of EB 6600/ha. This also assumes that SORDU could transport the charcoal to Addis Ababa at negligible cost when empty cattle trucks go for maintenance. Even if transport costs were included the activity would still be highly profitable (Coppock et al, 1990: p 27).

Table 7.7. Per cent charcoal yield from 350 kg of fresh wood for five *Acacia* species using local methods during November 1989 in the southern rangelands.<sup>1</sup>

	Species				
	<i>A. bussei</i>	<i>A. drepanolobium</i>	<i>A. etbaica</i>	<i>A. mellifera</i>	<i>A. seyal</i>
Per cent yield	25.0 <sub>x</sub>	19.5 <sub>y</sub>	17.4 <sub>yz</sub>	16.6 <sub>yz</sub>	15.8 <sub>z</sub>

<sup>1</sup> Each entry is the mean of four replications. Entries accompanied by the same letter ( $x, y, z$ ) were not significantly different ( $P < 0.01$ ) in a one-way ANOVA with an LSD (least significant difference) test. In addition, there was a significant effect of replication over time ( $P = 0.01$ ) which indicated that after the second or third use of the same charcoal-production pit, better conversion was achieved.

Source: Coppock et al (1990).



It is thus apparent that bush-encroached sites could be reclaimed using a combination of burning (to eliminate young trees), stumping and chemical application to kill larger trees, which could then be converted into charcoal to recoup the costs and provide profits for other local projects such as water tanks or maintenance of wells and ponds (see Section 7.3.1.1: *Water-development activities*). Chemicals are still needed because the stemmy regrowth of stumped trees is probably not useful for further conversion into charcoal (D. L. Coppock, ILCA, personal observation). This approach may be most successful during drought-recovery phases when grazing pressure is lower and cattle are less available for donation for community projects. Organised charcoal-making alone could also provide jobs for pastoralists during drought (see Section 7.3.3.7: *Mitigation of drought impact*). It is envisioned that this activity could be coordinated and regulated by SORDU. Alternatively, the Boran could attempt to control it themselves as part of bush clearing projects at the *deda* or *madda* level of resolution. Other pastoral groups near Awash Park have reportedly taken keen interest in conserving trees that are under pressure from neighbouring urban dwellers. The fact that the pastoralists are armed and the urban dwellers are not allows the pastoralists to regulate collection of fuel wood by the former (C. Schloeder, Ethiopian Wildlife Conservation Organisation, personal communication).

Despite the economic attractiveness of charcoal production, the main concern of SORDU is whether it could be controlled once knowledge of charcoal-making is more widely disseminated (Coppock, 1990b). Experiences elsewhere in Africa support this view (Moris, 1988). Charcoal-making is illegal on the Borana Plateau but small quantities are still produced (D. L. Coppock, ILCA, personal observation). It is likely that in addition to existing regulations, problems of labour, local transport and a low local demand would discourage wider production of charcoal (Coppock, 1990b). Conservatism is warranted as the continued rapid growth of local towns and a declining prosperity of many pastoralists may encourage faster rates of charcoal-making (and/or wood collection) in the future. In addition, there are no assurances that unregulated charcoal production could always be confined to less useful species of trees. To conclude, the major constraint against charcoal production is the ability of SORDU or the Boran themselves to regulate such activities.

**Site selection for bush control:** At this point it is important to again address the issue of the possible role of bush encroachment in protecting overgrazed sites and contributing to rehabilitation of the top soil through leaf litter (see Section 3.4.2: *Environmental*

*change*). There are no easy rules for site selection for bush control but a conservative approach would be to avoid bush control in those locations where a very reduced grass cover and heightened soil erosion is apparent. These would be difficult to burn, regardless. In contrast, those sites where the grass cover has recovered, but is only limited in terms of its accessibility, may be considered as priority sites for bush clearing. This would also provide management that is consistent with the hypotheses of the useful role of bush encroachment. Site selection must be undertaken in collaboration with the local people. As with other aspects of range improvements and site rehabilitation, the *deda* is probably the most appropriate level of social organisation with which to undertake bush control (Section 7.3.1.2: *Grazing management*).

**Role of browsing stock:** Pratt and Gwynne (1977: p 138) give examples where goats can be effective in controlling woody plants. They cite an example in Kenya (probably a well-managed ranch) where running goats at a rate of four goats per steer reduced the need for burning to once every six to eight years versus once every three to four years when cattle were managed alone. The Borana pastoralists, however, have stated that browsing stock cannot control bush encroachment (Coppock et al, 1990: p 21). This response is probably due to several factors: (1) the relatively low population density of browsers; (2) the high level of herding coordination probably required to assemble enough browsers to impact trees in a given site; and (3) once woody plants have reached a certain size, browsers can probably inflict only minor damage. In some local instances, however, browsing by small ruminants has probably contributed a degree of regulation. The closely pruned stands of stunted *Commiphora* spp at Did Hara may be one example (D. L. Coppock, ILCA, personal observation). Goats probably are most useful for controlling bush at the seedling stage and some detailed food-habits trials would be required to test this hypothesis. However, goats could also eat seedlings of valuable tree species and compete with calves for forages such as *A. tortilis* fruits (Coppock et al, 1986a; see below). Because of their large size and need to consume foods from large abundant trees, camels are relatively useless for bush control compared to small ruminants (Coppock et al, 1986a). In addition, with the exception of *A. brevispica*, camels do not appear to consume species that are regarded as encroachers (see Section 3.3.5.1: *Livestock food habits*). With the understanding that too many small ruminants may also be ecologically undesirable, the most effective policy to encourage more targeted impacts by small ruminants could be to provide better veterinary services (see Section



# Annex B

## Aids to Monitoring/ Data Sheets



# Standard to Metric Conversion Factors

## Length Conversion Factors

To convert from	to	multiply by
mile (US Statute)	kilometer (km)	1.609347
inch (in)	millimeter (mm)	25.4 *
inch (in)	centimeter (cm)	2.54 *
inch (in)	meter (m)	0.0254 *
foot (ft)	meter (m)	0.3048 *
yard (yd)	meter (m)	0.9144 *

## Area Conversion Factors

To convert from	to	multiply by
square foot (sq ft)	square meter (sq m)	0.09290304 E
square inch (sq in)	square meter (sq m)	0.00064516 E
square yard (sq yd)	square meter (sq m)	0.83612736 E
acre (ac)	hectare (ha)	0.4047

## Volume Conversion Factors

To convert from	to	multiply by
gallon (gal)	liter	3.7854118
U.S. liquid**		

## Mass Conversion Factors

<i>Mass (weight)</i>		
pound (lb)	kilogram (kg)	0.4535924
ton, 2000 lb	kilogram (kg)	907.1848

## Temperature Conversion Factors

### *Temperature*

degree Fahrenheit (F)	degree Celsius (C)	$t_c = (t_F - 32) / 1.8$
degree Fahrenheit (F)	kelvin (K)	$t_k = (t_F + 459.7) / 1.8$

### *Energy and heat*

British thermal unit (Btu)	joule (J)	1055.056
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## Speed

### *Velocity*

mile per hour (mph)	kilometer per hour (km/hr)	1.60934
mile per hour (mph)	meter per second (m/s)	0.44704

U. S. DEPARTMENT OF COMMERCE  
WEATHER BUREAU



**RELATIVE HUMIDITY  
and  
DEW POINT TABLE**

Pressure 27 Inches of Mercury

For use at elevations between 1,900 and 3,900 feet above sea level  
(In Alaska use at elevations between 1,700 and 3,600 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

**HOW TO USE THE TABLE**

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.









U. S. DEPARTMENT OF COMMERCE  
WEATHER BUREAU



RELATIVE HUMIDITY  
and  
DEW POINT TABLE

Pressure 25 Inches of Mercury

For use at elevations between 3901 and 6100 feet above sea level  
(In Alaska use at elevations between 3601 and 5700 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

WET BULB TEMPERATURES

13	14	15	16	17	18	19	20	21	22	23	24	25
-31	-14	-5	+2	7	11	15	18					
20	9	20	32	44	56	68	81	94				
21		-25	-11	-3	+3	8	13	16	20			
		11	23	34	46	58	70	82	94			
22		-46	-20	-8	-1	+5	10	14	18	21		
		3	14	25	36	48	59	71	83	95		
23		-34	-16	-6	+1	7	11	15	19	22		
		6	17	27	38	49	61	72	83	95		
24		-27	-12	-3	+3	9	13	17	21	24	23	
		9	19	30	40	51	62	73	84	96		
25		-52	-21	-9	-1	+5	10	14	18	21	24	
		2	12	22	32	42	53	63	74	85	96	
26		-36	-16	-6	+1	7	12	16	19	22		
		5	14	24	34	44	54	63	73	86	97	
27		-27	-12	-3	+4	9	13	17	21	24	26	
		8	17	26	36	46	56	66	76	87	97	
28		-56	-21	-9	0	+6	11	15	19	22	25	27
		1	10	19	29	38	48	57	67	77	87	98
29		-37	-16	-5	+2	8	12	16	20	23	26	29
		4	13	22	31	40	49	59	68	78	88	98
30		-27	-11	-2	+4	10	14	18	21	24		
		7	15	24	33	42	51	60	70	79	89	99
31		-54	-20	-8	0	+6	11	16	19	23	26	28
		1	10	18	26	35	44	52	61	71	80	90
32		-35	-15	-4	+3	9	13	17	21	24	27	30
		4	12	20	28	37	45	54	63	72	81	90
33		-25	-10	-1	+5	11	15	19	22	25	28	31
		7	15	22	30	39	47	56	64	73	82	91
34		-48	-18	-6	+2	8	12	17	20	24	27	30
		2	9	17	25	32	40	49	57	65	74	83
35		-31	-13	-3	+4	10	14	18	22	25	28	30
		4	12	19	27	34	42	50	58	67	75	83
36		-22	-9	0	+7	12	16	20	23	26	29	32
		7	14	21	29	36	44	52	60	68	76	84
37		-40	-16	-5	+3	9	14	18	22	25	28	30
		3	9	16	23	31	38	46	53	61	69	76
38		-27	-11	-1	+6	11	16	20	23	26	29	31
		5	12	19	26	33	40	47	55	62	69	77
39		-55	-19	-6	+2	8	13	18	21	25	27	30
		1	7	14	21	27	34	42	49	56	63	70
40		-32	-13	-2	+5	11	15	19	23	26	29	31
		3	10	16	23	29	36	43	50	57	64	71
41		-22	-8	+1	8	13	17	21	24	27	30	32
		6	12	18	25	31	38	44	51	58	64	71
42		-39	-15	-3	+4	10	15	19	23	26	29	31
		2	8	14	20	27	33	39	46	52	58	65
43		-25	-9	0	+7	13	17	21	24	27	30	32
		5	10	16	22	29	35	41	47	53	59	66
44		-48	-17	-4	+4	10	15	19	22	25	28	31
		7	13	18	24	30	36	42	48	54	60	66
45		-29	-10	0	+7	12	17	20	24	27	30	32
		4	9	15	20	26	31	37	43	49	55	61
46		-19	-5	+3	9	14	18	22	25	28	31	34
		6	11	17	22	27	33	38	44	50	56	62
47		-32	-12	-1	+6	12	16	20	24	27	30	32
		3	8	13	18	23	29	34	40	45	51	57
48		-20	-6	+2	9	14	18	22	25	28	31	34
		10	15	20	25	30	35	41	46	52	57	63
49		-35	-13	-2	+5	11	16	20	24	27	30	32
		2	7	12	17	21	26	31	37	42	47	53
50		-22	-7	+2	8	14	18	22	25	28	31	34
		4	9	13	18	23	28	33	38	43	48	53
51		-39	-14	-3	+5	11	16	20	24	27	30	32
		6	10	15	20	24	29	34	39	44	49	54
52		-24	-8	+1	8	13	18	22	25	28	31	34
		3	8	12	17	21	26	30	35	40	45	50
53		-45	-16	-3	+5	11	16	20	24	27	30	32
		1	5	9	14	18	22	27	32	36	41	46
54		-27	-9	+1	8	13	18	22	25	28	31	34
		3	7	11	15	19	24	28	33	37	42	47
55		-53	-17	-4	+4	11	16	20	24	27	30	32
		1	5	8	13	17	21	25	29	34	38	43

DRY BULB TEMPERATURES

13	14	15	16	17	18	19	20	21	22	23	24	25
-31	-14	-5	+2	7	11	15	18					
20	9	20	32	44	56	68	81	94				
21		-25	-11	-3	+3	8	13	16	20			
		11	23	34	46	58	70	82	94			
22		-46	-20	-8	-1	+5	10	14	18	21		
		3	14	25	36	48	59	71	83	95		
23		-34	-16	-6	+1	7	11	15	19	22		
		6	17	27	38	49	61	72	83	95		
24		-27	-12	-3	+3	9	13	17	21	24	23	
		9	19	30	40	51	62	73	84	96		
25		-52	-21	-9	-1	+5	10	14	18	21	24	
		2	12	22	32	42	53	63	74	85	96	
26		-36	-16	-6	+1	7	12	16	19	22		
		5	14	24	34	44	54	63	73	86	97	
27		-27	-12	-3	+4	9	13	17	21	24	26	
		8	17	26	36	46	56	66	76	87	97	
28		-56	-21	-9	0	+6	11	15	19	22	25	27
		1	10	19	29	38	48	57	67	77	87	98
29		-37	-16	-5	+2	8	12	16	20	23	26	29
		4	13	22	31	40	49	59	68	78	88	98
30		-27	-11	-2	+4	10	14	18	21	24		
		7	15	24	33	42	51	60	70	79	89	99
31		-54	-20	-8	0	+6	11	16	19	23	26	28
		1	10	18	26	35	44	52	61	71	80	90
32		-35	-15	-4	+3	9	13	17	21	24	27	30
		4	12	20	28	37	45	54	63	72	81	90
33		-25	-10	-1	+5	11	15	19	22	25	28	31
		7	15	22	30	39	47	56	64	73	82	91
34		-48	-18	-6	+2	8	12	17	20	24	27	30
		2	9	17	25	32	40	49	57	65	74	83
35		-31	-13	-3	+4	10	14	18	22	25	28	30
		4	12	19	27	34	42	50	58	67	75	83
36		-22	-9	0	+7	12	16	20	23	26	29	32
		7	14	21	29	36	44	52	60	68	76	84
37		-40	-16	-5	+3	9	14	18	22	25	28	30
		3	9	16	23	31	38	46	53	61	69	76
38		-27	-11	-1	+6	11	16	20	23	26	29	31
		5	12	19	26	33	40	47	55	62	69	77
39		-55	-19	-6	+2	8	13	18	21	25	27	30
		1	7	14	21	27	34	42	49	56	63	70
40		-32	-13	-2	+5	11	15	19	23	26	29	31
		3	10	16	23	29	36	43	50	57	64	71
41		-22	-8	+1	8	13	17	21	24	27	30	32
		6	12	18	25	31	38	44	51	58	64	71
42		-39	-15	-3	+4	10	15	19	23	26	29	31
		2	8	14	20	27	33	39	46	52	58	65
43		-25	-9	0	+7	13	17	21	24	27	30	32
		5	10	16	22	29	35	41	47	53	59	66
44		-48	-17	-4	+4	10	15	19	22	25	28	31
		7	13	18	24	30	36	42	48	54	60	66
45		-29	-10	0	+7	12	17	20	24	27	30	32
		4	9	15	20	26	31	37	43	49	55	61
46		-19	-5	+3	9	14	18	22	25	28	31	34
		6	11	17	22	27	33	38	44	50	56	62
47		-32	-12	-1	+6	12	16	20	24	27	30	32
		3	8	13	18	23	29	34	40	45	51	57
48		-20	-6	+2	9	14	18	22	25	28	31	34
		10	15	20	25	30	35	41	46	52	57	63
49		-35	-13	-2	+5	11	16	20	24	27	30	32
		2	7	12	17	21	26	31	37	42	47	53
50		-22	-7	+2	8	14	18	22	25	28	31	34
		4	9	13	18	23	28	33	38	43	48	53
51		-39	-14	-3	+5	11	16	20	24	27	30	32
		6	10	15	20	24	29	34	39	44	49	54



3901-6100 ASL

WET BULB TEMPERATURES

49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90		
86	-37	-9	+3	11	18	23	27	31	34	38	40	43	46	48	50	52	54	56	58	60	62	63	65	67	68	70	71	73	74	76	77	78	80	81	82	83	84	85	86	87	88	89	90
87	-17	-1	+8	15	21	26	30	33	36	39	42	45	47	50	52	54	56	58	60	62	63	65	66	68	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90	
88	-29	-6	+5	13	19	24	28	32	35	38	41	44	46	49	51	53	55	57	59	61	63	64	66	67	69	71	72	73	75	76	78	79	80	82	83	84	85	86	87	88	89	90	
89	-13	+1	10	17	22	27	31	34	37	40	43	46	48	50	53	55	57	59	61	62	64	65	67	69	71	72	73	75	76	77	79	80	81	83	84	85	86	87	88	89	90		
90	-22	-3	+7	14	20	25	29	33	36	39	42	45	47	50	52	54	56	58	60	62	63	65	67	68	70	71	73	74	76	77	78	80	81	82	83	84	85	86	87	88	89	90	
91	-40	-9	+3	12	18	23	28	32	35	38	41	44	47	49	51	53	55	57	59	61	62	64	65	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90	
92	-17	-1	+9	16	22	26	30	34	37	40	43	46	48	51	53	55	57	59	61	62	64	65	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90		
93	-29	-6	+6	14	20	25	29	33	36	39	42	45	48	50	52	54	56	58	60	62	63	65	67	69	71	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90	
94	-12	+2	11	18	23	28	32	35	38	41	44	47	49	51	54	56	58	60	62	63	65	67	69	71	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90		
95	-2	3	5	6	8	9	11	13	14	16	18	20	22	24	26	28	30	32	34	36	39	41	43	46	48	51	53	56	58	61	64	67	70	73	76	79	82	85	88	89	90		
96	-39	-8	+4	13	19	24	29	33	36	40	42	45	48	50	52	55	57	59	61	62	64	66	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90		
97	-16	0	+10	17	23	27	32	35	39	42	44	47	49	52	54	56	58	60	62	64	65	67	69	71	72	73	75	76	77	78	80	81	82	83	84	85	86	87	88	89	90		
98	-27	-4	+7	15	21	26	30	34	37	40	43	46	48	51	53	55	58	60	62	63	65	67	68	70	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90		
99	-54	-10	+3	12	18	24	29	33	36	40	43	45	48	50	53	55	57	59	61	63	65	66	68	70	71	73	74	76	77	79	80	81	82	83	84	85	86	87	88	89	90		
100	-19	-1	+9	17	22	27	32	35	39	42	45	47	50	52	54	56	58	60	62	64	66	68	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90			
101	-33	-6	+14	21	26	30	34	38	41	44	46	49	51	54	56	58	60	62	64	65	67	69	70	72	74	75	77	78	79	81	82	83	84	85	86	87	88	89	90				
102	-13	+2	12	19	24	29	33	37	40	43	46	48	51	53	55	57	59	61	63	65	67	68	70	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90			
103	-22	-2	+9	16	22	27	32	35	39	42	45	48	50	52	55	57	59	61	63	65	66	68	70	71	73	74	76	77	79	80	81	82	83	84	85	86	87	88	89	90			
104	-39	-7	+5	14	20	26	30	34	38	41	44	47	49	52	54	56	58	60	62	64	66	68	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90			
105	-14	+2	11	18	24	29	33	37	40	43	46	49	51	53	56	58	60	62	64	65	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90				
106	-25	-3	+8	16	22	27	32	36	39	42	45	48	50	53	55	57	59	61	63	65	67	69	70	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90			
107	-47	-8	+5	14	20	26	30	35	38	41	44	47	50	52	54	56	58	60	62	64	65	66	68	70	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90		
108	-16	+1	11	18	24	29	33	37	40	44	46	49	52	54	56	58	60	62	64	66	68	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90				
109	-27	-3	+8	16	22	27	32	36	39	43	46	48	51	53	56	58	60	62	64	66	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90				
110	-58	-9	+5	14	21	26	31	35	38	42	45	48	50	53	55	57	59	61	63	65	67	69	70	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90			
111	-17	+1	10	17	22	27	31	34	37	40	43	46	48	51	53	55	57	59	61	63	65	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90			
112	-29	-4	+8	16	22	27	32	36	40	43	46	49	51	54	56	58	60	62	64	66	68	70	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90				
113	-10	+5	14	21	26	30	34	38	41	44	47	49	52	54	56	58	60	62	64	66	68	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90				
114	-18	-1	10	17	22	27	31	34	37	40	43	46	48	51	53	55	57	59	61	63	65	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90			
115	-31	-4	+8	17	23	28	33	37	40	44	47	49	52	54	56	58	60	62	64	66	68	70	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90				
116	-10	+5	14	21	26	30	34	38	41	44	47	49	52	54	56	58	60	62	64	66	68	70	72	73	75	76	77	79	80	81	82	83	84	85	86	87	88	89	90				
117	-18	-1	10	17	22	27	31	34	37	40	43	46	48	51	53	55	57	59	61	63	65	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90			
118	-31	-3	+9	17	24	29	33	37	41	44	47	50	52	55	57	59	61	63	65	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90					
119	-9	+6	15	22	27	32	36	40	43	46	49	52	54	57	59	61	63	65	67	69	71	72	74	75	77	78	80	81	82	83	84	85	86	87	88	89	90						

DRY BULB TEMPERATURES

### Fahrenheit to Celsius Conversion Table

°F	°C	°F	°C	°F	°C	°F	°C
125	51.6	83	28.3	41	5.0	-1	-18.3
124	51.1	82	27.8	40	4.4	-2	-18.9
123	50.5	81	27.2	39	3.9	-3	-19.4
122	50.0	80	26.6	38	3.3	-4	-20.0
121	49.4	79	26.1	37	2.8	-5	-20.5
120	48.8	78	25.5	36	2.2	-6	-21.1
119	48.3	77	25.0	35	1.7	-7	-21.6
118	47.7	76	24.4	34	1.1	-8	-22.2
117	47.2	75	23.9	33	0.6	-9	-22.8
116	46.6	74	23.3	32	0.0	-10	-23.3
115	46.1	73	22.8	31	-0.6	-11	-23.9
114	45.5	72	22.2	30	-1.1	-12	-24.4
113	45.0	71	21.6	29	-1.7	-13	-25.0
112	44.4	70	21.1	28	-2.2	-14	-25.5
111	43.8	69	20.5	27	-2.8	-15	-26.1
110	43.3	68	20.0	26	-3.3	-16	-26.6
109	42.7	67	19.4	25	-3.9	-17	-27.2
108	42.2	66	18.9	24	-4.4	-18	-27.8
107	41.6	65	18.3	23	-5.0	-19	-28.3
106	41.1	64	17.8	22	-5.6	-20	-28.9
105	40.5	63	17.2	21	-6.1	-21	-29.4
104	40.0	62	16.7	20	-6.7	-22	-30.0
103	39.4	61	16.1	19	-7.2	-23	-30.5
102	38.9	60	15.5	18	-7.8	-24	-31.1
101	38.3	59	15.0	17	-8.3	-25	-31.6
100	37.7	58	14.4	16	-8.9	-26	-32.2
99	37.2	57	13.9	15	-9.4	-27	-32.7
98	36.6	56	13.3	14	-10.0	-28	-33.3
97	36.1	55	12.8	13	-10.5	-29	-33.9
96	35.5	54	12.2	12	-11.1	-30	-34.4
95	35.0	53	11.7	11	-11.7	-31	-35.0
94	34.4	52	11.1	10	-12.2	-32	-35.5
93	33.9	51	10.5	9	-12.8	-33	-36.1
92	33.3	50	10.0	8	-13.3	-34	-36.6
91	32.7	49	9.4	7	-13.9	-35	-37.2
90	32.2	48	8.9	6	-14.4	-36	-37.7
89	31.6	47	8.3	5	-15.0	-37	-38.3
88	31.1	46	7.8	4	-15.5	-38	-38.9
87	30.5	45	7.2	3	-16.1	-39	-39.4
86	30.0	44	6.7	2	-16.7	-40	-40.0
85	29.4	43	6.1	1	-17.2		
84	28.9	42	5.6	0	-17.8		



FUEL MODEL	DESCRIPTION
1	improved pasture / glades
224 2	pine or oak savanna
3	tallgrass prairie
6	cedar thickets
7	pine plantation / young regeneration
8	riparian bottoms or bottomland forest
9	oak or oak-pine woodland or forest

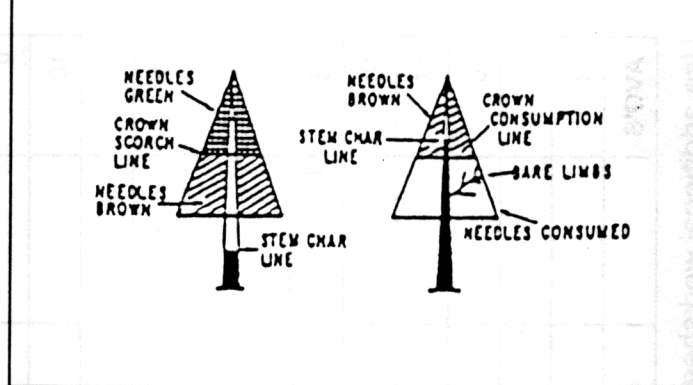


TABLE 2

OVERSTORY SCORCH PERCENT CLASS					
0	1	2	3	4	5
not burned	≤ 25%	> 25 ≤ 50%	> 50 ≤ 75%	> 75 ≤ 99%	> 99 ≤ 100%

TABLE 3

MIDSTORY SCORCH PERCENT CLASS					
0	1	2	3	4	5
not burned	≤ 25%	> 25 ≤ 50%	> 50 ≤ 75%	> 75 ≤ 99%	> 99 ≤ 100%

TABLE 4

SCORCH HEIGHT CLASS				
0	1	2	3	4
not burned	≤ 10 ft	> 10 ≤ 20 ft	> 20 ≤ 50 ft	> 50 ft

TABLE 5

CHAR HEIGHT CLASS				
0	1	2	3	4
not burned	≤ 5 ft	> 5 ≤ 10 ft	> 10 ≤ 20 ft	> 20 ft

TABLE 6

CHAR DEGREE (Plumb and Gomez 1983)		
LIGHT (1)	MEDIUM (2)	HEAVY (3)
spotty char or scorch with scattered pitting of bark	continuous charring with areas of minor reduction in bark thickness	continuous charring, pronounced reduction in bark thickness with underlying wood sometimes exposed

TABLE 7

BURN SEVERITY CLASS (USNPS 1991)					
	UNBURNED (0)	SCORCHED (1)	LIGHTLY BURNED (2)	MODERATELY BURNED (3)	HEAVILY BURNED (4)
Substrate (litter/duff)	not burned	litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	litter charred to partially consumed; upper duff layer burned; wood/leaf structures charred, but recognizable	litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply burned; wood/leaf structures unrecognizable	litter and duff consumed, leaving fine white ash; mineral soil visibly altered, often reddish
Vegetation (understory ≤ 3m tall)	not burned	foliage scorched and attached to supporting twigs	foliage & smaller twigs partially to completely consumed	foliage, twigs and small stems consumed	all plant parts consumed leaving some or no major stems/trunks



V IMMEDIATE POST-BURN EVALUATION EFFECTS

NATURAL COMMUNITY: \_\_\_\_\_

FUEL MODEL(S): \_\_\_\_\_

TRANSECT #: \_\_\_\_\_

PT	SCORCH		CHAR		BURN SEVERITY		COMMENTS
	HT	%	HT	DEG	ORGANIC SUBSTRATE	VEGETATION	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
<b>AVG'S</b>							

Use additional worksheets if necessary.

**Random Number Table**

13962 70992 65172 28053 02190 83634 66012 70305 66761 88344  
43905 46941 72300 11641 43548 30455 07686 31840 03261 89139  
00504 48658 38051 59408 16508 82979 92002 63606 41078 86326  
61274 57238 47267 35303 29066 02140 60867 39847 50968 96719  
43753 21159 16239 50595 62509 61207 86816 29902 23395 72640  
83503 51662 21636 68192 84294 38754 84755 34053 94582 29215  
36807 71420 35804 44862 23577 79551 42003 58684 09271 68396  
19110 55680 18792 41487 16614 83053 00812 16749 45347 88199  
82615 86984 93290 87971 60022 35415 20852 02909 99476 45568  
05621 26584 36493 63013 68181 57702 49510 75304 38724 15712  
06936 37293 55875 71213 83025 46063 74665 12178 10741 58362  
84981 60458 16194 92403 80951 80068 47076 23310 74899 87929  
66354 88441 96191 04794 14714 64749 43097 83976 83281 72038  
49602 94109 36460 62353 00721 66980 82554 90270 12312 56299  
78430 72391 96973 70437 97803 78683 04670 70667 58912 21883  
33331 51803 15934 75807 46561 80188 78984 29317 27971 16440  
62843 84445 56652 91797 45284 25842 96246 73504 21631 81223  
19528 15445 77764 33446 41204 70067 33354 70680 66664 75486  
16737 01887 50934 43306 75190 86997 56561 79018 34273 25196  
99389 06685 45945 62000 76228 60645 87750 46329 46544 95665  
36160 38196 77705 28891 12106 56281 86222 66116 39626 06080  
05505 45420 44016 79662 92069 27628 50002 32540 19848 27319  
85962 19758 92795 00458 71289 05884 37963 23322 73243 98185  
28763 04900 54460 22083 89279 43492 00066 40857 86568 49336  
42222 40446 82240 79159 44168 38213 46839 26598 29983 67645  
43626 40039 51492 36488 70280 24218 14596 04744 89336 35630  
97761 43444 95895 24102 07006 71923 04800 32062 41425 66862  
49275 44270 52512 03951 21651 53867 73531 70073 45542 22831  
15797 75134 39856 73527 78417 36208 59510 76913 22499 68467  
04497 24853 43879 07613 26400 17180 18880 66083 02196 10638  
95468 87411 30647 88711 01765 57688 60665 57636 36070 37285  
01420 74218 71047 14401 74537 14820 45248 78007 65911 38583  
74633 40171 97092 79137 30698 97915 36305 42613 87251 75608  
46662 99688 59576 04887 02310 35508 69481 30300 94047 57096  
10853 10393 03013 90372 89639 65800 88532 71789 59964 50681  
68583 01032 67938 29733 71176 35699 10551 15091 52947 20134  
75818 78982 24258 93051 02081 83890 66944 99856 87950 13952  
16395 16837 00538 57133 89398 78205 72122 99655 25294 20941  
53892 15105 40963 69267 85534 00533 27130 90420 72584 84576  
66009 26869 91829 65078 89616 49016 14200 97469 88307 92282  
45292 93427 92326 70206 15847 14302 60043 30530 57149 08642  
34033 45008 41621 79437 98745 84455 66769 94729 17975 50963  
13364 09937 00535 88122 47278 90758 23542 35273 67912 97670  
03343 62593 93332 09921 25306 57483 98115 33460 55304 43572  
46145 24476 62507 19530 41257 97919 02290 40357 38408 50031  
37703 51658 17420 30593 39637 64220 45486 03698 80220 12139  
12622 98083 17689 59677 56603 93316 79858 52548 67367 72416  
56043 00251 70085 28067 78135 53000 18138 40564 77086 49557  
43401 35924 28308 55140 07515 53854 23023 70268 80435 24269  
18053 53460 32125 81357 26935 67234 78460 47833 20496 35645

**% Mortality (Density) Data Sheet**

Burned Site						Un-Burned Site					
Transect	Length	Shrub #	Live	Dead	Shrubs/ha	Transect	Length	Shrub #	Live	Dead	Shrubs/ha
1						1					
2						2					
3						3					
4						4					
5						5					
6						6					
7						7					
8						8					
9						9					
10						10					
11						11					
12						12					
13						13					
14						14					
15						15					
16						16					
Mean						Mean					
Total						Total					
% Live Shrubs =						% Live Shrubs =					
% Live Shrub Reduction =						% Live Shrub Reduction =					

1 Hectare = 10,000m<sup>2</sup>

Shrubs/ ha = [(shrub # ) / (area m<sup>2</sup>)] X (10,000)

Mean = (Sum of all transects) / (# of transects)

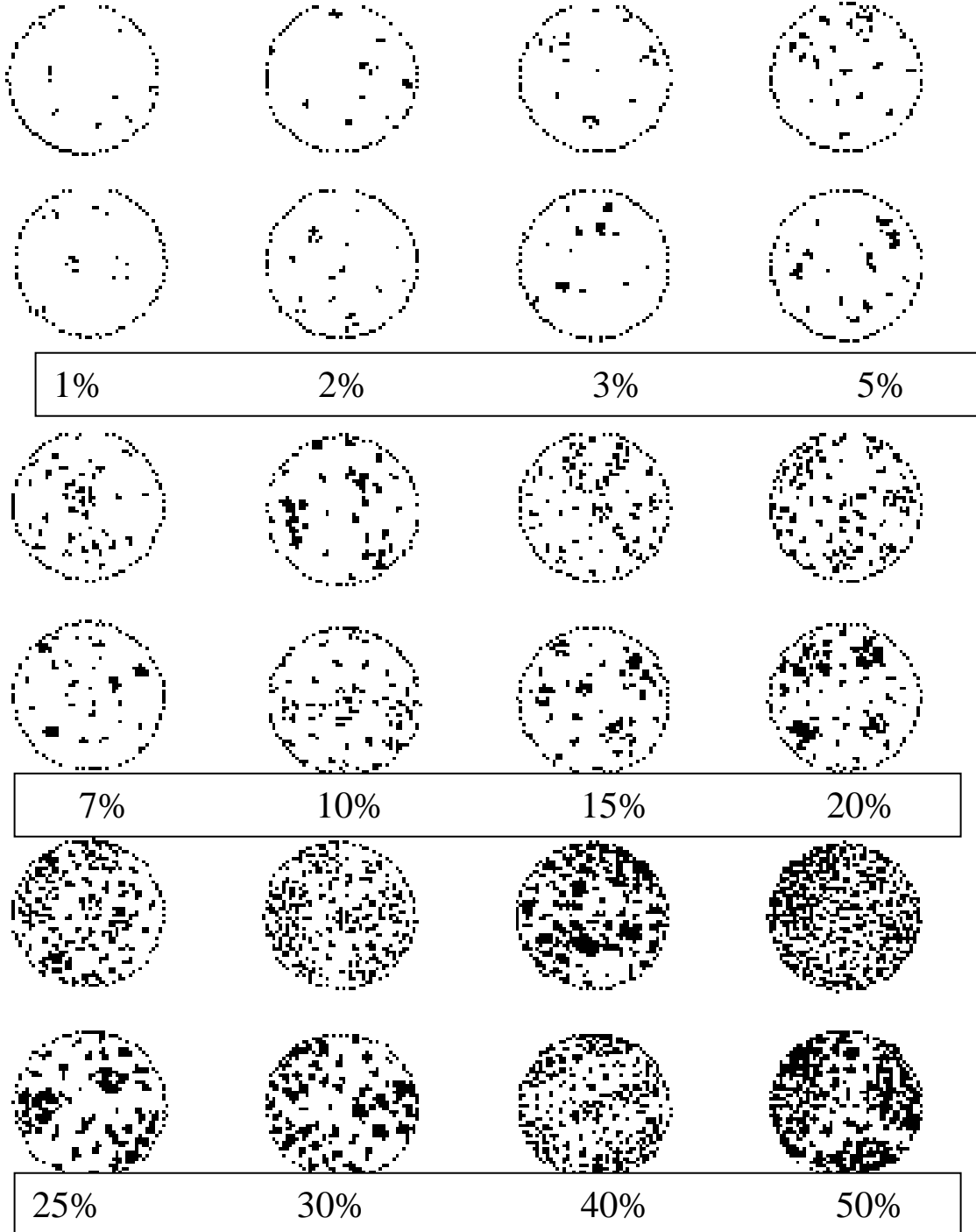
Total = the sum of all transects

% Live Shrubs = (Total Live/ Total Shrub # ) X 100%

% Live Shrub Reduction = 1 - (Total Live year 1 / Total Live year 2) X 100%

# Cover Estimation Aid

**Basal Cover-** the soil surface area occupied by the base of the plant.



## Data Sheet

### (Herbaceous Cover)

(Assumes 10 plots/ transect, using a standard frame size)

Burned Site				Un-Burned Site					
Transect	# Plots Averaged	Grass Cover	Forb Cover	Bare Ground	Transect	# Plots Averaged	Grass Cover	Forb Cover	Bare Ground
1	10				1	10			
2	10				2	10			
3	10				3	10			
4	10				4	10			
5	10				5	10			
6	10				6	10			
7	10				7	10			
8	10				8	10			
9	10				9	10			
10	10				10	10			
11	10				11	10			
12	10				12	10			
13	10				13	10			
14	10				14	10			
15	10				15	10			
16	10				16	10			
<b>Mean</b>					<b>Mean</b>				

Transect #1 (Burn)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

Transect #2 (Burn)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

Transect #3 (Burn)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

Transect #1 (Un-burned)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

Transect #2 (Un-burned)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

Transect #3 (Un-Burned)			
# Plot	Grass Cover	Forb Cover	Bare Ground
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
Mean			

**FRWS 5410**  
**Lab I: Cover**

Name(s): \_\_\_\_\_ Date: \_\_\_\_\_ Page \_\_\_ of \_\_\_

Site Location (GPS): \_\_\_\_\_

Site Comments: \_\_\_\_\_

Method: DAUBENMIRE (0.10 m<sup>2</sup>) Response Variable(s): \_\_\_\_\_

Plot No.	Cover Classes (%)						Cover Class Mid-Pt
	T	0.1-5	6-25	26-50	51-75	76-95	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

*The mid-points for the six classes, respectively, are 2.5, 15.5, 38.0, 63.0, 85.5, and 98.0. If a plant occurred across 30 plots a total of 20 times, and was found 9 times in cover class 1, 7 times in cover class 2, 2 times in cover class 3 and 2 times in cover class 4, then the overall average would be [(10 x 0) + (9 x 2.5) + (7 x 15.5) + (2 x 38.0) + (2 x 63.0)] divided by 30, or 11.1%.*





# REPORT

## Management/ Qualitative Monitoring Evaluation

Region:
Area:
Site Name/ number:
GPS Location:
Marker (yes/ no):
Date:
Observers/ Photographers:
Direction of Photo:

Map
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Directions:




## Glossary

### Prescribed Fire and Rangeland Management

**accelerated erosion:** erosion much more rapid than normal, natural, or geologic erosion, primarily as a result of the influence of the activities of humans, or, in some cases, of other animals or natural catastrophes that expose bare surfaces, for example, fires.

**aerial fuels:** the layer of fuels that is above the surface fuels, including living tree and shrub crowns, mosses, lichens, vines, and dead branch material.

**available fuel:** the portion of the total fuel on the site that would actually burn under a given set of environmental conditions.

**backing fire:** a fire, or that part of a fire, spreading or set to spread into the wind, or down a slope.

**basal cover:** the vertical projection of the root crown onto the ground.

**Btu:** British thermal unit. The amount of heat needed to raise the temperature of one pound of water (one pint) one degree Fahrenheit.

**burn severity:** a qualitative assessment of the heat pulse directed toward the ground during a fire. Burn severity relates to soil heating, large fuel and duff consumption, consumption of the litter and organic layer beneath trees and isolated shrubs, and mortality of buried plant parts.

**chain:** unit of measure in land survey, equal to 66 feet (20 meters) (80 chains equal one mile). Commonly used to report fire perimeters and other fireline distances, chains can be easily converted to acreage (e.g., 10 square chains equal one acre).

**climax:** the highest ecological development of a plant capable of perpetuation under the prevailing climatic and conditions (Range Term Glossary Committee 1974).

**colonizer:** species that establish on a burned (or otherwise denuded) site from seed (Stickney 1986).

**combustion:** consumption of fuels by oxidation, evolving heat, flame, and/or incandescence.

**convection column:** the thermally induced ascending column of gases, smoke, water vapor, and particulate matter produced by a fire.

**cover:** the area on the ground covered by the combined aerial parts of plants expressed as a percent of the total area. (See basal cover and foliar cover.)

**crown fire:** a fire that advances by moving among crowns of trees or shrubs.

**crown scorch:** causing the death of tree foliage by heating it to lethal temperature during a fire, although the foliage is not consumed by the fire. Crown scorch may not be apparent for several weeks after the fire.

**crown scorch height:** the height above the surface of the ground to which a tree canopy is scorched.

**dead fuels:** naturally occurring fuels without living tissue, in which the moisture content is governed almost entirely by absorption or evaporation of atmospheric moisture (relative humidity and precipitation).

**decreaser species:** plant species of the original vegetation that decrease in relative amount under overuse by grazing or browsing animals. Commonly termed decreaseers.

**density:** the number of plants or parts of plants per unit area.

**desired plant community:** a plant community which produces the kind, proportion, and amount of vegetation necessary for meeting or exceeding the land use plan goals and activity plan objectives established for the site.

**duff:** the partially decomposed organic material of the forest floor that lies beneath the freshly fallen twigs, needles and leaves. The fermentation and humus layers of the forest floor (Deeming et al. 1977).

**ecological site:** a distinctive geographic unit that differs from other kinds of geographic units in its ability to produce a characteristic natural plant community. An ecological site is the product of all the environmental factors responsible for its development. It is capable of supporting a native plant community typified by an association of species that differs from that of other ecologic sites in the kind or portion of species or in total production.

**fine fuels:** small diameter fuels such as grass, leaves, draped pine needles, and twigs, which when dry, ignite readily and are rapidly consumed.

**fire behavior:** the manner in which a fire burns in response to the variables of fuel, weather, and topography.

**fire regime:** periodicity and pattern of naturally occurring fires in a particular area or vegetative type, described in terms of frequency, biological severity, and areal extent (Tande 1980).

**fire whirl:** a spinning, vortex column of ascending hot air and gases rising from a fire and carrying aloft smoke, debris, and flame. Fire whirls range from a foot or two in diameter to small tornadoes in size and intensity. They may involve the entire fire area or only a hot spot within the area.

**flame length:** the average length of flames when the fire has reached its full, forward rate of spread, measured along the slant of the flame from the midpoint of its base to its tip.

**forb:** a plant with a soft, rather than permanent woody stem, that is not a grass or grasslike plant.

**frequency:** a quantitative expression of the presence or absence of individuals of a species in a population; the ratio between the number of sample units that contain a species and the total number of sample units.

**fuel:** combustible plant material, both living and dead that is capable of burning in a wildland situation.

**fuel arrangement:** the spatial distribution and orientation of fuel particles within a fuel bed.

**fuel bed:** an array of fuels usually constructed with specific loading, depth, and particle size, to meet experimental requirements; also commonly used to describe the fuel composition in natural settings.

**fuel bed depth:** average height of surface fuels contained in the combustion zone of a spreading fire front.

**fuel continuity:** the degree or extent of continuous or uninterrupted distribution of fuel particles in a fuel bed, a critical influence on a fire's ability to sustain combustion and spread. This applies both to aerial fuels and surface fuels.

**fuel loading:** the weight of fuels in a given area, usually expressed in tons per acre, pounds per acre, or kilograms per square meter.

**fuel model:** a characterization of fuel properties of a typical field situation. A fuel model contains a complete set of inputs for the fire spread model.

**fuel moisture content:** the amount of water in a particle of fuel, usually expressed as a percentage of the oven dry weight of the fuel particle.

**fuel size class:** a category used to describe the diameter of down dead woody fuels. Fuels within the same size class are assumed to have similar wetting and drying properties, and to preheat and ignite at similar rates during the combustion process.

**grazing management (strategy):** the manipulation of the grazing use on an area in a particular pattern, to achieve specific objectives.

**ground fire:** fire that burns the organic material in the soil layer (e.g. a "peat fire") and often also the surface litter and low-growing vegetation.

**ground fuels:** all combustible materials below the surface litter layer, including duff, tree and shrub roots, punky wood, dead lower moss and lichen layers, and sawdust, that normally support glowing combustion without flame.

**growth stage:** the relative ages of individuals of a species, usually expressed in categories such as seedlings, juvenile, mature, and decadent.

**head fire:** a fire front spreading, or ignited to spread with the wind, up a slope, or influenced by a combination of wind and slope.

**heat per unit area:** total amount of heat released per unit area as the flaming front of the fire passes, expressed as Btu/square foot; a measure of the total amount of heat released in flames.

**heavy fuels:** dead fuels of large diameter (3.0 inches or larger) such as logs and large branchwood.

**hydrophobicity:** resistance to wetting exhibited by some soils, also called water repellency. The phenomena may occur naturally or may be fire-induced. It may be determined by water drop penetration time, equilibrium liquid-contact angles, solid-air surface tension indices, or the characterization of dynamic wetting angles during infiltration.

**ignition technique:** the configuration and sequence in which a prescribed fire is ignited. Patterns include, for example, spot fire, strip-head fire, and ring fire.

**intensity:** the heat released per unit of time for each unit length of the leading fire edge. The primary unit is Btu per lineal foot of fire front per second (Byram 1959 in Albin 1976).

**introduced plant species:** a species not a part of the original fauna or flora of an area.

**invader species:** plant species that were absent in undisturbed portions of the original vegetation and will invade under disturbance or continued overuse. Commonly termed invaders.

**key forage species:** forage species of particular importance in the plant community or which are important because of their value as indicators of change in the community.

**ladder fuels:** fuels that can carry a fire from the surface fuel layer into the aerial fuel layer, such as a standing dead tree with branches that extend along its entire length.

**litter:** the top layer of forest floor, typically composed of loose debris such as branches, twigs, and recently fallen leaves or needles; little altered in structure by decomposition. The L layer of the forest floor (Deeming et al. 1977). Also loose accumulations of debris fallen from shrubs, or dead parts of grass plants laying on the surface of the ground.

**live fuel moisture content:** ratio of the amount of water to the amount of dry plant material in living plants.

**live fuels:** living plants, such as trees, grasses, and shrubs, in which the seasonal moisture content cycle is controlled largely by internal physiological mechanisms, rather than by external weather influences.

**live herbaceous moisture content:** ratio of the amount of water to the amount of dry plant material in herbaceous plants, i.e., grasses and forbs.

**live woody moisture content:** ratio of the amount of water to the amount of dry plant material in shrubs.

**midflame windspeed:** the speed of the wind measured at the midpoint of the flames, considered to be most representative of the speed of the wind that is affecting fire behavior.

**moisture of extinction:** the moisture content of a specific fuel type above which a fire will not propagate itself, and a firebrand will not ignite a spreading fire.

**mosaic:** the intermingling of plant communities and their successional stages in such a manner as to give the impression of an interwoven design (Ford-Robertson 1971).

**native species:** a species which is a part of the original fauna or flora of the area in question.

**nutrient:** elements or compounds that are essential as raw materials for organism growth and development, such as carbon, oxygen, nitrogen, and phosphorus. There are at least 17 essential nutrients.

**off-site colonizers:** plants that germinate and establish after a disturbance from seed that was carried from off of the site (Stickney 1986).

**onsite colonizers:** plants that germinate and establish after a disturbance from seed that was present on the site at the time of the disturbance (Stickney 1986).

**one-hour timelag fuels:** dead fuels consisting of dead herbaceous plant material and roundwood less than 0.25 inches (0.64 cm) in diameter, expected to reach 63 percent of equilibrium moisture content in one hour or less.

**one-hundred hour timelag fuels:** dead fuels consisting of roundwood in the size range from 1.0 to 3.0 inches (2.5 to 7.6 cm) in diameter, estimated to reach 63 percent of equilibrium moisture content in one hundred hours.

**one-thousand hour timelag fuels:** dead fuels consisting of roundwood 3.0 to 8.0 inches (7.6 to 20.3 cm) in diameter, estimated to reach 63 percent of equilibrium moisture content in one thousand hours.

**organic matter:** that fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population.

**palatability:** the relish that an animal shows for a particular species, plant or plant part; how agreeable the plant is to the taste.

**passive crown fire:** a fire in the crowns of trees in which trees or groups of trees torch, ignited by the passing front of the fire. The torching trees reinforce the spread rate, but these fires are not basically different from surface fires.

**pH:** the negative logarithm (base =10) of the hydronium ion concentration, in moles per liter. It is a numerical measure of acidity or alkalinity on a scale of 1 to 14, with the value of 7.0 being neutral.

**phenology:** the relationship of the seasonal sequence of climatic factors with the timing of growth and reproductive phases in vegetation, such as initiation of seasonal growth, time of blooming, time of seed set, and development of new terminal buds (Daubenmire 1968b).

**pile burning:** burning of logging slash that has been arranged into individual piles.

**prescribed burning:** controlled application of fire to wildland fuels in either their natural or modified state, under specified environmental conditions that allows the fire to be confined to a predetermined area, and produce the fire behavior and fire characteristics required to attain planned fire treatment and resource management objectives.

**prescribed fire:** an intentionally or naturally ignited fire that burns under specified conditions that allow the fire to be confined to a predetermined area and produce the fire behavior and fire characteristics required to attain planned fire treatment and resource management objectives.

**prescription:** a written statement defining the objectives to be attained as well as the conditions of temperature, humidity, wind direction and speed, fuel moisture, and soil moisture, under which a fire will be allowed to burn. A prescription is generally expressed as acceptable ranges of the prescription elements, and the limit of the geographic area to be covered.

**probability of ignition:** the chance that a firebrand will cause an ignition when it lands on receptive fuels.

**productivity:** weight of dry matter produced in a given period by all the green plants growing in a given space (Daubenmire 1968b)..

**rate of spread:** the speed with which a fire moves in a horizontal direction across the landscape, usually expressed in chains per hour or feet per minute.

**reaction intensity:** the rate of heat release, per unit area of the fire front, expressed as heat energy/area/time, such as Btu/square foot/minute, or Kcal/square meter/second.

**relative humidity:** the ratio, in percent, of the amount of moisture in a volume of air to the total amount which that volume can hold at the given temperature and atmospheric pressure. Relative humidity is a function of the actual moisture content of the air, the temperature, and the atmospheric pressure (Schroeder and Buck 1970).

**residence time:** the time required for the flaming zone of the moving front of a fire to pass a stationary point; the total length of time that the flaming front of the fire occupies one point.

**root crown:** a mass of woody tissue from which roots and stems originate, and which are often covered with dormant buds (James 1984); same as lignotuber.

**running crown fire:** a fire moving in the crowns of trees, dependent upon, or independent from the surface fire.

**seedbank:** the supply of viable seeds present on a site. Seeds include those recently dispersed by plants, long-lived seeds buried in organic and soil layers, or those stored in cones in a tree canopy.

**seral:** pertaining to a succession of plant communities in a given habitat leading to a particular climax association; a stage in a community succession (Cooperrider et al. 1986).

**Serotinous cones:** Seed bearing fruits which do not open until subjected to temperatures of 45 to 50 C (113 to 122 F), causing the melting of the resin bond that seals the cone scales and releasing seed.

**severity:** a qualitative assessment of the heat pulse directed toward the ground during a fire. Burn severity relates to soil heating, large fuel and duff consumption, consumption of the litter and organic layer beneath trees and isolated shrubs, and mortality of buried plant parts.

**slash:** concentrations of wildland fuels resulting from human activities such as logging, thinning, and road construction, and natural events such as wind. Slash is composed of branches, bark, tops, cull logs, uprooted stumps, and broken or uprooted trees.

**smoldering phase:** a phase of combustion that can occur after flames die down because the reaction rate of the fire is not high enough to maintain a persistent flame envelope. During the smoldering phase, gases condense because of the cooler temperatures, and much more smoke is produced than during flaming combustion.

**species composition:** a term relating the relative abundance of one plant species to another using a common measurement; the proportion (percentage) of various species in relation to the total on a given area.

**spot fire:** fire caused by flying sparks or embers outside the perimeter of the main fire.

**spotting:** production of burning embers in the moving fire front that are carried a short distance ahead of the fire, or in some cases are lofted by convective action or carried by fire whirls some distance ahead.

**structure (vegetative):** the form or appearance of a stand; the arrangement of the canopy; the volume of vegetation in tiers or layers (Thomas 1979).

**succession:** the process of vegetational development whereby an area becomes successively occupied by different plant communities of higher ecological order (Range Term Glossary Committee 1974).

**surface area to volume ratio:** the ratio between the surface area of an object, such as a fuel particle, to its volume. The smaller the particle, the more quickly it can become wet, dry out, or become heated to combustion temperature during a fire.



**surface fire:** fire that burns surface litter, dead woody fuels, other loose debris on the forest floor, and some small vegetation.

**surface fuels:** fuels that contact the surface of the ground, consisting of leaf and needle litter, dead branch material, downed logs, bark, tree cones, and low stature living plants.

**survivors:** plant species with established plants on the site that can vegetatively regenerate after the fire (Stickney 1986).

**ten-hour timelag fuels:** dead fuels consisting of roundwood 0.25 to 1.0 inches (0.6 to 2.5 cm) in diameter, estimated to reach 63 percent of equilibrium moisture content in ten hours.

**timelag:** the time necessary for a fuel particle to lose or gain approximately 63 percent of the difference between its initial moisture content and its equilibrium moisture content.

**torch:** ignition and subsequent envelopment in flames, usually from bottom to top, of a tree or small group of trees.

**treatment:** a procedure whose effect can be measured and compared with the effect of other procedures. Examples include a fall burned prescribed fire, an unburned "control", or an area burned with a specific ignition method or pattern.

**utilization rates (limits):** the proportion of the current year's forage production that is removed by grazing or browsing animals. It may refer to particular species or to the entire plant community and is usually expressed as a percentage.

**vapor pressure:** the contribution to total atmospheric pressure due to the presence of water molecules in the air (Schroeder and Buck 1970).

**vegetative regeneration:** development of new aboveground plants from surviving plant parts, such as by sprouting from a root crown or rhizomes. Even if plants form their own root system, they are still genetically the same as the parent plant (Zasada 1989).

**vegetative reproduction:** establishment of a new plant from a seed that is a genetically distinct individual (Zasada 1989).

**weight:** as used in vegetation inventory and monitoring, the total biomass of living plants growing above the ground in a given area at a given time.

**wildfire:** a free burning and unwanted wildland fire requiring a suppression action.