Fire Management Practices to Improve Air Quality

K-STATE Research and Extension

Department of Agronomy MF3072 Prescribed Burns

All rangeland fires produce smoke that is carried away from the burned area where it can be detrimental to air quality for thousands of people. Smoke does not readily disperse and can be carried like a cloud for long distances. Smoke elements that are of the most concern are particulate matter, ozone precursors, and the combination of both that results in regional haze. Each component is associated with negative effects on visibility, health, and air quality.

Particulate matter is a tiny piece of solid or liquid that is carried and suspended by wind. Particulate matter is defined by its diameter in microns[1] as PM_{10} and $PM_{2.5}$. About 70 percent of the particles produced are $PM_{2.5}$. Heavier particles generally settle close to the smoke source, while smaller particles can be carried by the wind for many miles. Particulate matter can be removed from the air by rain and snow and gravitational pull. If they are inhaled, smaller particles can cause health problems, including shortness of breath, coughing, and irregular heartbeat.

Ozone precursors consist of nitrogenous gases (NO_X) and volatile organic compounds (VOC) released by burning fuels that, under certain meteorological conditions, form ozone (O_3) downwind. Environmental conditions that increase the chance of ozone formation are sunshine, high temperatures, temperature inversions, and calm winds (Figure 1). Ozone is the major component of smog. It causes coughing, throat irritation, and worsening of asthma and emphysema. Ozone precursors are not cleaned from the air by precipitation but eventually disperse naturally. Ozone precursors from prescribed burns in Kansas have been detected as far away as New York.

Ozone affects both humans and plants. Human health effects include coughing, pain with deep breathing, reduced lung function, and shortness of breath. In plants, long-term exposure to ozone can kill trees, increase needle drop in conifers, and increase a tree's susceptibility to root rot.

Regional (or visible) haze — formed by the combination of NO_X and $PM_{2.5}$ — results in impaired visibility and atmospheric discoloration due to the scattering of light particles. Haze formation is exacerbated by high humidity and calm winds. Much of the concern with regional haze is aesthetic, although its formation indicates the presence of health-impairing components (see above).

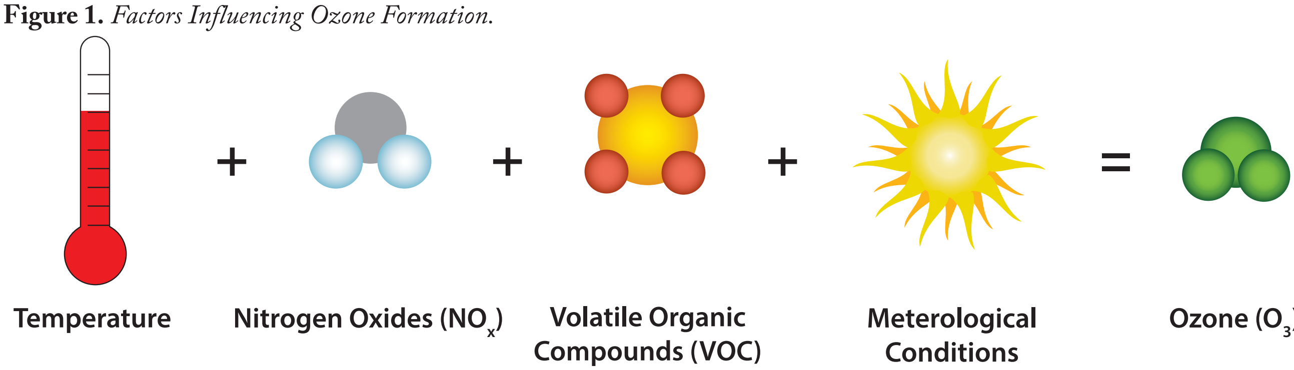
Fire management practices attempt to reduce the negative effects of smoke that impact air quality, visibility, health, and safety. Fire management practices reduce smoke-related air quality problems in three ways:

- **avoiding** smoke movement into sensitive areas;
- **diluting** smoke concentrations through management and planning; and
- **reducing** the total amount of smoke produced.

Avoiding air quality problems. Conduct prescribed burns when weather patterns are favorable for dispersion. Then smoke is carried away from sensitive areas that were identified as part of the prescribed burn

[1] The subscript in this measurement refers to the size of the particulate matter measured in microns. In this case, PM_{10} refers to particulate matter 10 microns in diameter.

Figure 1. *Factors Influencing Ozone Formation.*



Source: *Smoke and Air Quality for Land Managers*. 2010. NWCG Smoke Committee and University of Idaho, used with permission.

planning process. Weather components such as wind speed and direction, mixing height, transport winds, inversions, humidity, and atmospheric stability can affect the direction and distance smoke travels and how close to the ground it remains. Use weather predictions to determine optimal times to burn to avoid producing smoke that will affect sensitive areas. When available, use modeling predictions that indicate where smoke plumes will travel. Avoid burning when the plume is directed toward urban areas. One such model is available at *www.ksfire.org*.

When smoke has the potential to drift over sensitive areas and burning cannot be delayed, notify health authorities in advance so air quality alerts can be distributed and people notified to take action, such as staying inside, to avoid breathing the smoke.

Diluting the effects of smoke production. Scheduling burning activities so large quantities of smoke are not produced from the combined emissions from many fires. Coordinate burning activities across the air shed to spread them across a larger time frame to maintain air quality at attainment levels in sensitive areas.

Reducing emissions. Use fuel management to produce less smoke. Reduce the quantity of fuel burned and increase fuel combustion efficiency.

Less smoke is generated when fewer acres are burned if fuel loads are equivalent. Burn only when a specific management objective requires it. Some livestock management practices generate more fuel per acre. These include patch burning with grazing, deferred grazing rotations, and no grazing. In the case of patch burning, fewer total acres are burned each year, which offsets the higher fuel loads generated. Fuel loads are also reduced when burning occurs at frequent intervals, reducing fuel buildup, especially of woody species. Livestock or wildlife grazing decreases fuel loads, but range managers should be certain that enough fuel remains to carry the fire and meet management objectives.

Reducing the time fuels burn decreases the amount of time that smoke is produced. Woody fuels will smolder long after the fire front has passed. Burning rangeland at intervals that keep woody species from encroaching will aid smoke management. Extinguish smoldering fuels immediately after the burn. Where appropriate, piling fuels such as dead trees decreases burning time, but may have temporary negative consequences on the vegetation under the pile due to the high temperatures generated by the fire.

Efficient fuel combustion results in less smoke production. Smoke production is increased by the presence of green vegetation, which contains a higher concentration of water than dormant vegetation. Dry fuels burn more efficiently. Grasses and forbs burn cleaner than shrubs and woody species. Adequate wind speed is important for flaming combustion, which is more efficient than smoldering combustion. Combustion efficiency decreases all air quality pollutants in the smoke except NO_X and CO_2.

Consider trade-offs when selecting the fire management practices best suited to a particular situation. Backfires burn more efficiently than headfires, but headfires take less time to burn. Increased burning efficiency results in increased levels of NO_X and CO_2 in the smoke but fewer overall pollutants.

Frequent burning results in a larger number of acres burned each year, but also in more rapid burn completion times due to fewer woody fuels. Frequent burning can also reduce wildfire occurrence, extent, and severity. Wildfire conditions provide few options for smoke management.

When planning a prescribed burn, consider not only the effects of the burn on or near the area burned, but also the effects of smoke on areas downwind. Individual producers using practices that mitigate the effects of the smoke from their fire can reduce air quality effects from the combined smoke from many fires. Cleaner air benefits everyone.

Adapted from

National Wildfire Coordinating Group Smoke Committee. Publication year unknown. *Smoke management and air quality for land managers: An online training resource — Lesson 3: Smoke management techniques* (online). Idaho State University. *www.frames.gov/partner-sites/emissions-and-smoke/educational-resources/tutorial/* Downloaded 9 Nov. 2012.

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Wade, Dale and Hugh Mobley. 2007. *Managing smoke at the wildland-urban interface*. U.S. Forest Service Southern Research Station Gen. Tech. Rep. SRS-103. p. 2-3.

Weather Components that Affect Smoke Dispersion

The following weather components affect smoke dispersion, both by themselves and in combination.

Air Pressure: Pressure is the force per unit area exerted by the weight of the atmosphere. Avoid burning during periods of high pressure, which cause stagnant air conditions that keep smoke from rising.

Atmospheric Stability: Atmospheric stability is the resistance of the atmosphere to vertical motion. Moderately unstable conditions improve smoke dispersal and are preferred for prescribed burning, but highly unstable conditions such as fronts increase the chance of a prescribed burn escaping and becoming a wildfire.

Lapse Rate: Lapse rate is the rate of decrease in air temperature as elevation increases. It is an inverse measure of atmospheric stability. A plume of smoke will continue to rise and expand until it cools to the temperature of the surrounding air, at which point the smoke may sink back toward the ground and negatively affect air quality. The location where the plume sinks may be many miles from the fire location.

Temperature Inversions: When a layer of warm air lies above a cooler layer of ground air, a temperature inversion exists. When rising smoke encounters this layer of warm air, it cannot disperse upward and remains near the ground. This can cause visibility and health problems in the area near the fire.

Mixing Height: Mixing height refers to the height above ground level at which vertical air mixing air occurs. A low mixing height indicates that the air is stagnant, and smoke is held close to the ground. The lowest mixing heights often occur at night and early morning, with the highest mixing heights occurring in mid- to late afternoon. Since the mixing height generally decreases rapidly from late afternoon to nightfall, plan to burn during the middle of the day, when mixing heights are typically highest.

Wind: While other factors control the vertical movement of smoke, wind is responsible for controlling its horizontal movement. Winds are typically light and variable when the atmosphere is stable. Wind speeds near the ground are often lower than transport wind speeds located higher in the atmosphere. As air cools at night, it becomes heavier and can drift down valleys and drainages. This type of wind is often responsible for overnight smoke intrusions into populated areas.

Humidity: Water vapor combined with smoke can decrease visibility to near zero. Smoke particles act as condensation nuclei, promoting the fog formation. Temperatures near the dew point and low wind speeds promote fog formation. The combination of smoke and fog results in extremely low visibility, which increases traffic fatalities.

Fog and smoke, alone and in combination, can move down drainage areas for miles, causing dispersion problems at locations distant from the actual fire. As smoke moves down the drainage basin, the air temperature becomes lower, the relative humidity becomes higher, and fog formation is more likely. Other locations where fog is likely to form are near streams, lakes, marshes, and wetlands.

Humidity affects fuel moisture. As fuel humidity increases, combustion is slowed and more fuel is consumed during the smoldering phase. Smoldering combustion produces twice the amount of particulates as flaming combustion. High humidity conditions result in a decrease of emissions carried into the smoke plume, and lower lofting of the smoke plume into the atmosphere, both of which decrease smoke dispersion.

Combustion of high-humidity fuels also releases water vapor that decreases visibility.

Rain removes small smoke particles from the air, reducing smoke concentrations and improving visibility.

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