Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

The Fire Risks of a Corn Field Maze

Brian K. Ashton

Boise Fire Department, Boise, Idaho

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

Certification Statement

I herby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

Signed: ___________________________________

Abstract

One of the most rapidly expanding agricultural based activities in the nation is the corn field maze. The problem is that the Boise Fire Department has not identified the fire risks associated with corn field mazes. The purpose of this research is to identify the fire risks of a corn field maze and develop a prevention strategy for the hazards associated with corn field maze attractions.

A descriptive research methodology was used to address the following research questions:

a) Will a mature corn field burn, and if so, what type of fire behavior exists?

b) What are the fire risks of a corn field maze?

c) What effect does weather have on fire behavior in a corn field?

d) What effect does topography have on fire behavior in a corn field?

e) What effect does fuel moisture have on fire behavior in a corn field?

f) What human factors are associated with fires in corn field mazes?

The author's research procedures utilized relevant literature review of fire behavior components, fire behavior prediction, contributing human factors in corn maze fires, and corn maze operations literature. Three interviews of experts; one in fire behavior prediction, one in corn plant biology and agricultural practice, and the third a master in corn maze design and operations. A simple experiment was conducted to confirm the flammability of mature corn plants. The results of the study agree with the data uncovered in the literature review and confirm the extreme life loss potential of a corn field maze fire. The recommendations include

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

the development of a public awareness campaign, and the education of maze operators, fire department personnel, adults, and school aged children to the dangers of corn maze attractions.

Table of Contents

Table of Figures

Appendices

Introduction

Each year, fire departments all across the nation spend millions of dollars and man-hours working to prevent the loss of life to fires in buildings. Professional fire inspectors carefully walk through businesses and public venues to ensure that exits are clear and easily located, aisle ways are unobstructed and wide enough, combustibles are not in the way or stacked too high, and that fire hazards are mitigated. But every fall, in communities across the globe, entrepreneurs sell tickets and profit from putting people in corn mazes which break every one of these fire prevention principles (B. Herbst, personal communication, August 2, 2011). Customers line up and pay to walk into a field of flammable corn leaves grown twelve feet high, with exits blocked or nonexistent, aisle ways which dead end and leave no way out, while campfires often burn on the perimeter of the maze for effect.

Some jurisdictions have noticed, others have not. Some fire departments sponsor these events as fund raisers each year. A few entities have noticed and created awareness programs, but the fact remains that there is work to be done to reduce the risk of a devastating loss of life in the corn fields of America.

How does the fire service move forward and take a proactive stance on this community risk? It is as simple as imagining the horrific scene after a fire starts on the perimeter of a corn field maze during a warm October afternoon, with a steady autumn breeze to fan the flames. The fire begins small and innocent looking until it is pushed into the evenly spaced, tightly packed canopy of fuel. As the wind pushes the flames deeper into the field, the smoldering stalks make it difficult to access the flames to fight the fire. The head of the fire grows and preheats the fuel in front of it and intensifies in length and width. The smoke column lays flat as the wind pushes it into the fuel bed and begins to obscure pathways and aisles in the maze. Participants in the

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

corn maze begin to panic and realize the difficulty of finding their way out. The local fire department has been called, but is having difficulties locating the field because of no physical address, lack of pre-planning and the smoke column laying flat and making the source of the fire difficult to find. When the fire department arrives, the gruesome scene is that only created by the Hollywood movie industry. Bodies of men, women and children lay amongst the smoldering remains of what was previously a fun filled family activity.

The purpose of this research is to identify the fire risks of a corn field maze and develop a prevention plan for the hazards associated with corn field maze attractions. The fire risks could be intentional or deliberate acts of an arsonist, or unintentional causes like a dropped cigarette or a campfire ember which blows into the field. Mitigating these risks seems straightforward; the real work is in making this information available to fire departments nationwide. A prevention plan for reducing risk would include a walk through with both suppression and prevention personnel. This two pronged approach creates unity within the fire department, and allows for the best practices of each discipline to come to the surface to prevent loss of life. To achieve the goals of this research, the following questions will be answered;

1. Will a mature corn field burn, and if so, what type of fire behavior exists?
2. What are the fire risks of a corn field maze?
3. What effect does weather have on fire behavior in a corn field?
4. What effect does topography have on fire behavior in a corn field?
5. What effect does fuel moisture have on fire behavior in a corn field?
6. What human factors are associated with fires in corn field mazes?

This research paper will relate the existing science of wild land fire spread and behavior to that of fire in a corn field, with corn leaves as the fuel that carries or supports combustion. After an exhaustive search of the internet and local libraries, this author has not found any published data on fire spread and behavior in corn fields. To this end, corn will be placed into a classification of fuels which have already been studied. From this, predictions of rate of spread and flame length calculations can be made. To reinforce these predictions, an experiment was used to measure rate of spread in a controlled environment to match the predictions of wild fire publications.

Background and Significance

The Boise Fire Department is located in the southern portion of the state of Idaho and serves the incorporated city limits of Boise in Ada County. The city covers 98 square miles with a population of over 225,000 people. The profile of Boise includes high density urban as well as commercial, rural areas, farms, ranches, and sprawling growth occurring in the surrounding foothills area (HelloMetro, 2011). The Boise Fire Department provides fire protection to the citizens of Boise as well as the citizens of Garden City through a Joint Powers Agreement. Boise Fire is a paid career department and provides a wide range of emergency response services, fire prevention, and community education. In addition, Boise provides advanced and basic life support response, hazardous materials response, urban search and rescue, wild land fire response, and others (Doan, 2009). As of January 1, 2011, Boise's staffing level was 287 full time positions. The Boise Fire Department suppression employees currently work a 48/96 schedule. Boise responded to 16,323 calls for service during 2010, of which 10,569 were medical in nature (S.K. Stephens, personal communication, May 10, 2011). Boise Fire has automatic response contracts with all neighboring departments in Ada County, including Eagle, Meridian and Kuna fire departments. These automatic aid agreements have increased call volumes over the last 10 years. Another change which has come from automatic aid agreements is the type of calls that the city firefighters respond to. Because most of Ada County is farmland, calls into these areas require special knowledge of address blocks, geographical landmarks, and even landowner names for property identification. Call types range from routine medicals to agricultural machinery accidents and fires, brush and crop fires, severe weather incidents, and shop accidents to name a few. Because agriculture is such a large business in the state of Idaho, fire departments must adapt to the challenges of each district and be prepared for incidents of any type.

Agriculture in Idaho represents a substantial portion of the state's economy and impacts an excess of 100,000 jobs (Taylor, 2001). Sixteen percent of private sector employment in Idaho is directly related to agribusiness. Agricultural products for 2005 were valued at $4,484,275,000, with slightly over half of that from the sale of livestock and dairy products. The 2002 Census of Agriculture by the USDA reports that twenty-two percent of the land or 11.77 million acres (47,630 km^2) in Idaho is used for agricultural purposes. The average farm size is 70 acres (1.9 km^2) and the average age of the farm operator is 54.1 years (Parker, 2011). Specific to Ada County, harvested cropland as a percentage of land in farms is 25.17% and irrigated harvested cropland as a percentage of land in farms is 95.31% (Parker, 2011). Because of the close proximity to the population center of Boise, the farmlands surrounding Boise are a source of work and play for many residents in the area. It is easy to identify work related activities in these farmlands, but what types of recreational activities exist in these areas? According to the Idaho Tourist website, hunting, fishing, four-wheel driving, mud racing, equestrian events, horseback riding and roping, petting farms, and harvest activities top the list

(Idaho Department of Commerce, 2011). Of most importance, in the last ten years, the proliferation of corn field mazes makes up the fastest growing agricultural event in the state.

The term is “Agritourism” and it includes corn mazes, hay rides, petting zoos, pumpkin picking, and other harvest season activities ("Wiki," 2011). Agritourism, as it is defined most broadly, involves any agriculturally-based operation or activity that brings visitors to a farm or ranch. Agritourism has different definitions in different parts of the world, and sometimes refers specifically to farm stays, as in Italy. Elsewhere, agritourism includes a wide variety of activities, including buying produce direct from a farm stand, navigating a corn maze, picking fruit, feeding animals, or staying at a bed and breakfast on a farm (“Wiki”, 2011). According to Hillary Lowe, owner of “The Farmstead” attraction in Boise’s suburb Meridian Idaho, the attendance at their corn maze has been on the rise since 2006 when they acquired their farm. Lowe estimates between ten and eighteen thousand people visit their corn maze each season, which runs September through November, weather permitting (H. Lowe, personal communication, July 10, 2011). In a conversation with Brett Herbst, owner of “The Maize”, a company dedicated to designing and cutting custom corn field mazes throughout the United States, in 2011, he will design 250 mazes and personally supervise the cutting of over 135 of these unique creations. “Business is steady, the average corn maze attraction will see ten thousand visitors per season,” which runs October through November in most climates (B. Herbst, personal communication, July 20, 2011).

The proximity of the Boise Fire department to agricultural land results in emergency response to these areas. Unfortunately, there has not been enough consistency in Boise Fire’s records management system to track fires of this type. Fires which have occurred in fields have been coded as grass fires, wild land fires, rubbish fires etc… A search of the Boise Fire

Department records management system attributed only one call to an agricultural field in the past ten years. This is likely the result of coding omissions in the Firehouse© software system because the person entering the data would have to choose “fire in cultivated crops” and then specifically state a corn field in their narrative section of the report. Furthermore, there is no nationwide standard entry in the National Fire Incident Reporting System for specifically recording what type of cultivated crop is involved (NIFRS Support, personal communication, August 9, 2011).

In the past, there has been no effort or resources committed to the risk of fire in corn mazes. It is possible that it has been overlooked or the risk of fire has been underestimated. A similar situation has occurred in our nations night clubs, which have been in operation for a long time, but until the Station Nightclub fire in New Jersey, did not get the fire prevention efforts they deserved. This research is an opportunity to correct the past, and protect the future.

Presently, this author found no recorded deaths or large scale incidents involving fire in a corn maze: however, there have been deaths and property loss as a result of fire in corn fields. Regardless of the fact that a death has not occurred, the risk of death or property loss from fire in a corn maze remains high. Additionally, it has been the philosophy of the Boise Fire Department and most fire departments to be pro active in risk reduction and not wait for an incident to occur before presenting solutions to the identified problem. Furthermore, Boise Fire Department’s vision statement reads “Protecting lives and property is our contribution to making Boise the most livable city in the country" (Doan, 2009). In the future, the probability of death and property damage as the result of fire in a corn maze will be on the increase if some type of risk reduction program is not implemented. The research and findings of this paper will provide the information to change that probability and prevent the loss of life and property.

Of the five goals of the United States Fire Administration (USFA), this research clearly addresses the first two; 1.) Reduce risk at the local level through prevention and mitigation. 2.) Improve local planning and preparedness. This research will attempt to establish that there is risk for fire in a corn maze, combined with the associated loss of life that could occur. In addition, preventing fires from occurring and mitigation of ignition factors will address this risk reduction goal of the USFA. This reduction will occur only with buy in from local fire departments, to evaluate the risks in their own districts, and use the information in this paper to spread the word. The second goal to improve local planning and preparedness will also be met by the local fire department going out to see these agricultural attractions and preplanning response routes, evacuations, fire suppression activities, medical responses, etc… These two goals of the USFA could be met with one visit to the field to meet and discuss risk factors with the owner/operators.

As part of the coursework of the Emergency Risk Reduction class as part of the Executive Fire Officer Program, it was stressed that a successful prevention program will take place only if prevention and suppression forces within an organization are integrated into one team (Executive Analysis, 2011, student manual 4-5). The fact is that "both response and prevention have the same goal; to prevent or reduce harm to the public from fire, preventable injuries, etc. Same mission. Same team. Same organization. Same community. The synergy that results from integrating operations and prevention make both functions considerably more effective" (Executive Analysis, 2011, chapter 4-7). As part of the recommendations of this research, suppression and prevention will be asked to jointly walk through agricultural attractions to discuss risk factors and prevention issues, thereby working together to reduce risk from both angles.

Literature Review

The purpose of this literature review was to examine and summarize the research findings of others regarding the factors presented by corn field mazes and ways to reduce the risks of the effects of corn maze fires. Because there is not much written on corn maze fires to date, this review will shed light on the science of fire behavior, fuel types, weather factors, and any other published data that contributed to the study of fire in a corn field. Specifically, the review focuses on modeling corn leaves as a fuel type, and then identifying the factors which cause the leaves to burn at different rates.

The United States Forest Service has been working with fuel modeling for over 50 years (Stephens, 2005). The concept began when prescribed fire was first introduced into Florida's Osceola National Forest in 1943. Fires in forested areas or open plots of land also became a hazard to life and limb, and the United States Government took an aggressive stance on fighting fire in these areas (Stephens, 2005). There are a number of different models available, from basic to rather complex, depending on the complexity of the fire area being modeled. For a particular growing plant, grass, tree or shrub, there are certain fire characteristics which can be predicted. The idea behind fuel modeling is to identify the primary carrier of fire in a given plot of land, and match that fuel with one of the pre-described fuel models. Once the match is made, the rate of fire spread per unit of wind speed can be calculated. A predominant book used for fuel modeling is "Standard Fire Behavior Fuel Models; A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model" (Scott & Burgan, 2005). This book serves as a guide for fire managers in the Forest Service, Bureau of Land Management and other federal agencies to predict fire behavior and spread for a given type of fuel. Temperature, relative humidity, fuel moisture content, and wind speed are just a few components taken into account when predicting fire behavior. Outputs from these data inputs are rate of spread, expressed in chains (66 feet) per hour, and flame length, expressed in feet. These are the factors that fire behavior analysts need to know in order to predict where a fire will go and how fast it will get there, as well as what type of extinguishment method would be safest and most useful. It should be noted that the entire set of terms and calculations presented in “Standard Fire Behavior Fuel Models” is not described or used here. Rather, only the key terms and concepts that will assist the reader understand the spread of fire in a given fuel are presented.

The National Wildfire Coordinating Group (NWCG) is a committee made up of fire managers and state and federal firefighters which publishes and updates training materials for wild land firefighters worldwide. Of particular importance to this research is the course guide for the NWCG course; S-190 Wildland Fire Behavior. From this instructor’s guide, the following three factors are the contributors to fire spread. Topography - the “lay of the land” and its influence to fire behavior. Fuels- the type, dryness, arrangement, size and shape of a fuel and how these properties affect fire spread. Weather- factors of wind, temperature, precipitation, relative humidity are all factors to fire behavior (Introduction to Wild, 2006).

Topography

Topography is the configuration of the earth’s surface including its relief and the position of its natural and man-made features. Topography can vary from the flat plains of the central United States to the Rocky Mountains in the west (Introduction to Wild, 2006, chapter 2). The most influential facet of topography for this research is the concept of aspect; the direction toward the sun that the fuel bed faces. For instance, a northern aspect faces North, which shades the fuels from the sun. Characteristics of a northern aspect are heavier and more compact fuel, lower temperatures, higher humidity, and higher fuel moisture. Conversely, southern facing slopes are the opposite, with sun exposure, lighter and sparse fuel, lower humidity, higher temperatures, and lower fuel moistures. These are the topographical influences which are most critical in terms of the start and spread of wild fires.

Fuels

The NWCG states that fuel type is the next component of fire spread and behavior. Wild land fire fuels are grouped into fuel types based on the primary fuel that carries the fire. There are six major fuel types; grass, grass-shrub, shrub, timber understory, timber litter, and slash-blow down (Introduction to Wild, 2006, chapter 2). The purpose of breaking down fuels into major types is to allow for the prediction of how fire will spread and react to weather and topography variables. Since all fuels do not burn the same for a given temperature, humidity, wind etc…, these fuel types group many fuels down into six main categories for easy fire behavior calculations. The grass and grass-shrub types are important to the discussion of corn as a fuel. The shrub, timber and slash types represent fuels which are too heavy and bulky to classify corn into. For this reason, they will not be discussed or included in this study.

Hal E. Anderson (1982) published "Aids to Determining Fuel Models" which shows that grasses are broken down into three models that are used for fire behavior calculations. Of upmost consideration in the literature, Anderson describes 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. This is the fuel model in which standing brown corn is placed. See

Appendix A; photographs 6, 7, and 8 for examples of fuels fitting this model (Anderson, 1982, p. 6).

An interview with fire behavior analyst Lance Okeson from the Boise District Bureau of Land Management with over twenty five years of experience evaluating fuels and fire behavior greatly influenced this research (L.Okeson, personal communication, June 5, 2011). Lance was selected because of his experience in developing burn plans for prescribed fires. His job is to sample what fuels exist in an area and then to place those fuels into an existing fuel model. Okeson concurs with placing brown (cured) corn into the grass model 3 as suggested by Anderson's (1982) procedures. Okeson chose the "Very High Load, Humid Climate Grass" as the fuel model GR9 from the Standard Fire Behavior Fuel Models book of 2005, which incidentally includes fuel model 3 from Anderson's work from 1982. He notes the uniform distribution of the corn plants, the compactness of the spacing, and the height of the corn being greater than six feet tall. He made the correlation between corn and cattail plants which grow similar to the leaves on corn stalks. Cattail plants may also fall in the GR9 fuel models. Okeson's chief responsibility in fire management is to predict fire behavior in different fuel types and estimate rates of spread and which fuels will burn and which will not. Okeson agreed with the notion that corn leaves will carry the fire. In addition, under the right conditions, those being relative humidity below 40 percent and wind of at least 5 miles per hour, significant fire behavior could be expected. Okeson was stunned that this topic had not yet been addressed, with the number of corn field mazes and the probability for fire spread.

Scott and Burgan (2005) detail the Grass Fuel Type Models (GR). The primary carrier of fire in the GR fuel models is grass. Grass fuels can vary from heavily grazed grass stubble or sparse natural grass to dense grass more than 6 feet tall (See Figure 1, p. 34). Fire behavior

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

varies from moderate spread rate and low flame length in the sparse grass to extreme spread rate and flame length in the tall grass models. All GR fuel models are dynamic, meaning that their live herbaceous fuel load shifts from live to dead as a function of live herbaceous moisture content (Scott & Burgan, 2005, p. 25). The effect of live herbaceous moisture content on spread rate and intensity is strong. In other words, as a plant moves from a high moisture content of 300 percent while developing to a low moisture content of 30 percent when it is dying, it is referred to as "dead" or "cured" (National Wildfire Coordinating Group, 1994). See the video for an example of flame heights possible from YouTube®, http://www.youtube.com/watch?v=qoiqJHmgJ8k&feature=related

Fuel Moisture

Related to this is fuel moisture which is the measure of the amount of water in a fuel, expressed as a percentage of the oven-dry weight of that fuel. How well a fuel will ignite and burn is dependent, to a large extent, on its moisture content (National Wildfire Coordinating Group, 1994, p. 220). Dry fuels will ignite and burn much more easily than the same fuels when they are wet. Before a wet fuel can burn, the moisture it contains must evaporate, which requires heat. As fuel moisture increases, the amount of heat required to ignite and burn that fuel also increases. The heat source required for this is typically the sun; however the wind will dry the moisture out of the fuel (National Wildfire Coordinating Group, 1994, pp. 203-208). In autumn, when irrigation stops and corn plants begin to dry out, the amount of moisture becomes critical to this research.

To shed light on fuel moisture and how corn leaf moisture could be calculated for this research, an interview was conducted with Steve Gray, senior manager at Campbell Tractor and Implement Company of Nampa, Idaho (S. Gray, personal communication, June 14, 2011). He has been in the agriculture industry for his entire career, and is the source for many in southwest

Idaho for farming techniques and harvest maximization. His background is in biology and he applies that knowledge to crop development. He was selected for interview to assist in the author's understanding of the growth cycle of corn, and plant moisture content around harvest time. Gray noted that moisture content is the key measure during the harvest. However, the moisture content that is measured during the harvest of corn is kernel moisture inside the corn cob. When corn is combined and processed, the machinery measures the moisture of the corn kernels. Optimum moisture content is between 15 and 18 percent. Gray feels confident that if the moisture inside the cob is at that level, the moisture in the leaves on the outside is much lower. As for the growth cycle of corn, it is usually irrigated in Idaho through August, with harvest in September. Within a month of harvest, the corn leaves have turned brown (cured) and the existing moisture remaining in the plant is in the lower stalk at ground level.

Surface Area to Volume

There are two physical properties which contribute to the ability of corn to carry fire. The first is surface area to volume ratio. This relates to the amount of the outer surface of the fuel that is exposed to the air. The more surface exposed, the more easily the fuel will dry and burn. Smaller (fine) fuels have a higher surface area to volume ratio than larger (heavy) fuels (National Wildfire Coordinating Group, 1994, p. 167). Corn leaves resemble grass as they are very thin, but are wide and flat, which makes their surface to air ratio quite high. This physical characteristic allows air to circulate and assist in drying the fuel rapidly which promotes fire spread. Fuel arrangement is the other physical property worth noting. Vertical arrangement is the alignment of a fuel to its vertical axis. Corn is a perfect example of a perfectly uniform, vertical arranged fuel (L. Okeson, personal communication, June 5, 2011). This physical property allows the leaves to support combustion and spread from leaf to leaf quickly because of the uniformity of the fuel arrangement between the corn stalks. Corn also has a uniform horizontal arrangement which allows it to communicate fire on its horizontal axis from stem to stem. Okeson believes that agricultural fields represent nearly perfect forms of horizontal and vertical arrangement. This video, a cornfield fire in action in Meadow Grove Nebraska shows the leaves carry the fire: http://www.youtube.com/watch?v=BsRrAY8fDfc&NR=1

Weather

The significance of weather to the development and spread of fire in any fuel cannot be understated for this research. Goodson (2003) makes it clear, of the three factors, topography, fuels, and weather, the effects of weather on a fire, is the most dramatic and variable of the three. It is important to note that weather and its influence on wild land fire behavior is usually a key factor in firefighter safety and survival on the fire line. A case in point is the 1994 South Canyon fire near Glenwood Springs, Colorado, where 14 firefighters perished. The investigative report found that weather information was neither requested nor supplied to the fire crews who were overrun by a sudden and unexpected blowup (sudden increase in fire intensity and spread). The report concluded that weather “contributed significantly” to the accident and the resulting fatalities (Butler et al., 2009).

Perry (1990) points out that the basic principles and concepts of fire weather as they relate to wild land fire behavior include: air temperature, relative humidity (RH), precipitation, atmospheric stability, and wind.

Air Temperature

Temperature is a measure of the warmth or coldness of a substance- in this case, the air. The main source of heat for the outside air is solar energy from the sun. The temperature of the ground and of the fuels is primarily due to direct solar radiation. Higher fuel temperatures make fuels more susceptible to ignition. Heated fuels burn much easier than those at lower temperatures (Goodson, 2003, p. 25). Temperature is one of the weather factors which can be easily forecasted within a day or days and with significant accuracy.

Relative Humidity

Goodson (2003) states that relative humidity is the percentage of moisture in a volume of air relative to the total amount of moisture which that volume of air can hold at the given temperature and atmospheric pressure. For example, when the relative humidity is 58 percent, the air holds only 58 percent of the moisture that it could possibly hold at that temperature and atmospheric pressure. When air holds the maximum amount of moisture, the air is saturated, and its relative humidity is 100 percent (Goodson, 2003). Relative humidity can range from 1% (very dry) to 100% (very moist). Low relative humidity is an indicator of high fire danger. Moisture in the atmosphere, whether in the form of water vapor, cloud droplets, or precipitation, is the primary weather element that affects fuel moisture content and the resulting flammability of wild land fuels (Perry, 1990). The amount of moisture that fuels can absorb from or release to the air depends largely on relative humidity. Light fuels, such as grass, gain and lose moisture quickly with changes in relative humidity. Heavy fuels such as logs and twigs, respond to humidity changes much more slowly. Perry (1990) notes that in regard to fire behavior, fifty percent relative humidity is about the percentage where most fine fuels stop spreading under normal conditions. Thirty percent relative humidity is considered favorable for fire spread. Ten percent relative humidity is considered critical for fire spread (Perry, 1990).

Goodson (2003) notes that temperature and relative humidity have an inverse relationship. When temperature increases, relative humidity decreases. When temperature decreases, relative humidity increases. In the early morning hours, temperature typically reaches its lowest point and relative humidity reaches its highest point. As the sun rises and the temperature increases, relative humidity decreases. When the temperature reaches its maximum for the day (usually mid to late afternoon) relative humidity decreases to a minimum (Goodson, 2003). This is the time when fine fuel moisture reaches its minimum. As the sun sets the temperature drops and the relative humidity increases. This relationship is critical to the understanding of when a corn field would be susceptible to ignite and burn. Mid to late afternoon when fuel temperatures are high and humidity is low would be the most conducive to fire spread (National Wildfire Coordinating Group, 1994).

Wind

According to Perry (1992), wind is the most critical weather element affecting wild land fire behavior, the most difficult to predict, and the most variable in both time and location. This variability (especially in rough terrain) can pose safety and fire control problems, which can result in firefighter fatalities. Its principal characteristics are its direction, speed, and turbulence (gustiness). Surface winds are strongly affected by topography and by local heating and cooling (Goodson, 2003, p. 27). Wind impacts the fire environment in a number of ways. Wind increases the supply of oxygen to the fire, which intensifies flame length and heat production. Wind will determine the direction of fire spread, by pushing the fire in the path of least resistance, oftentimes against topographic factors. Wind will increase the drying of the fuel directly ahead of the flame front, which lowers fuel moisture and increases fire activity. Wind will carry sparks and firebrands ahead of the main fire causing spot fires which can entrap firefighters or civilians (Goodson, 2003, p. 28).

In this fire in north central Iowa, the author notes the presence of wind and how fast the fire spread: http://www.youtube.com/watch?v=jRfFuguMuuo&feature=related

Precipitation

Precipitation is the measured amount of rainfall in a given location (Goodson, 2003). Precipitation can have a dramatic affect on fire behavior if enough is received over a period of time. For the purposes of this research, precipitation is important because of its impact of increased fuel moisture in the corn leaves. A brief heavy downpour can have the same effect as a longer duration, misting rain on the fuel. What is important is that precipitation and its effects on corn leaves can give off this moisture with the right temperature and wind in less than one hour, and be ready for ignition again (L.Okeson, personal communication, June 5, 2011).

Atmospheric Stability

According to the NWCG (2006), atmospheric stability is defined as the atmospheres resistance to upward or downward movement. Unstable air encourages upward vertical movement and generally increases fire behavior. Conversely, stable air discourages the vertical movement of air and tends to reduce fire activity (NWCG, 2006). Many visual indicators exist for unstable air conditions. Dust devils, gusty winds, cumulus clouds (rounded tops with flat bases) and thunderstorm development are all clues to the observer that unstable conditions exist, and that a fire that starts in any given fuel will grow quickly (Goodson, 2003). According to Perry (1992), the typical fire season at any given location has numerous hot and dry days, yet wildfires are usually clustered within relatively short periods. These periods are characterized by one (or a combination of) critical fire weather conditions: strong and shifting winds, very low relative humidity, high temperature, unstable atmosphere, and the presence of dry lighting (Perry 1992). An unstable atmosphere contributes significantly to fire spread because of the associated gusty winds, and is therefore a key component of this study.

Weather has a dramatic impact on a fire in corn or any wild land fuel. The effects of air temperature, relative humidity (RH), precipitation, wind, and atmospheric stability make up the components of weather which impact how and when a fire will burn. It is important to note from a risk reduction standpoint, these elements of weather can be forecasted and readily obtained for the average person.

Human Factors

This researcher conducted exhaustive searches of the Idaho National Incident Fire Reporting System, as well as the records management system of the Boise Fire Department. The goal of this search was to uncover corn field fire incidents and use the reported fire cause information to find the human factors that played a role in the fire. The results were virtually non-existent. Boise Fire Marshal Ronald Amandus cites the subjectivity of persons involved at a fire in an agricultural field, feeling that data about how a fire started is often missing or not collected at all (R. Amandus, personal communication, July 6, 2011). One reason for this is because it is difficult for an incident commander to determine dollar loss to a field of grain or corn. For Boise Fire, if the loss is not suspected to be arson, and the dollar loss is below five hundred dollars, a fire investigator is not called to the scene. This leaves the cause of the fire coded as “undetermined” and short stops good data collection. Often times, the cause of the fire is unintentional, such as a controlled burn getting away from a farmer and igniting the field. In this case, the cause is usually recorded as “unintentional”, which can lead to incomplete documentation by the report writer (R. Amandus, personal communication, July 6, 2011). There are a few reasons for this. If a fire investigator does not investigate the fire, the responding fire company often does not take the time to ask questions or determine the cause of the fire. Included in this information would be the materials ignited, the heat source, factors contributing to fire spread and others. If the fire company does not gather this information, and code it into the run report, the opportunity to record data for others is missed.

For this research paper, the attempt was also made to review the causes of fires in cornfields using NIFRS on the national level. This attempt also proved to be futile, due in part to the fact that there is not a good process for researching NIFRS records for all states at one time. According to the Idaho Fire Marshal's office, a person must search each state individually for run report information, after first having obtain permission to do so for each state (M. Larson, personal communication, June 3, 2011). Because of the difficulties encountered in the local and state level search for Idaho, the national database search process was not pursued.

It should be noted that these failures in locating data will be used as part of the recommendations to be made. Proper coding of all facets of incident response allows users of this information to access it at a later date.

There were, however, a number of contributing articles found on the internet search engine Google. Of significant interest was a fire in Paradise Township, Pennsylvania in 2001, which occurred when standing corn was cut down in order to create a parking lot for visitors. The corn fodder was left on the ground, and the heat of a vehicles catalytic converter ignited the field. Over 30 cars were burned, a farmhouse was threatened and damage was estimated at $750,000 (Andrew C, 2003). The human factors resulting in this fire are the corn maze operators not using good judgment, and allowing cars onto the dry corn in the first place. To obtain a contributing viewpoint, an interview was conducted with a corn maze developer and designer who operates numerous corn field mazes each autumn. His name is Brett Herbst and he owns "The Maize" located in Spanish Fork, Utah. He has been in the corn maze development business for fifteen years and personally designs corn mazes. He has developed operational plans and

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

marketing tools for operators of corn mazes. His designs have been sold in markets worldwide. He was selected because of his time in the industry and his knowledge of both design and operation of corn mazes. Herbst was not surprised in a discussion of this particular fire, and he adds "in addition to the presence of vehicles, is the decision of many maze operators to use campfires to light the entrances of their mazes for affect. Some mazes are even haunted, with inadequate lighting, where oftentimes patrons may revert to using lighters or matches to light their surroundings." Although Brett has not heard of a fire in a corn maze that ended in tragedy, he knows that hazards exist. "Safety is the first thing, heat, cold, rain, tripping hazards, fire, … all of these are risks that must be mitigated for continued successful operation of a corn maze. Insurance agents look closely at those things." (B. Herbst, personal communication, July 20, 2011).

Another article about this incident offers additional information. The Vegetable Growers Network (2007) published an article about this fire in their newsletter in 2007. As a result of this fire, which occurred in 2001, the Maryland Fire Marshal issued "Minimum Life Safety Guidelines for Corn Maze Amusement Attractions in the State of Maryland." They include 13 provisions that govern the operations of corn maze attractions. These provisions include no smoking, no fireworks, no more than 200 guests per acre, no flame generating devices, fire lanes, and parking rules (McCallum, 2008) (See Appendix H).

Roger Johnson, the Indiana State Fire Marshal, says "A cornfield fire is about the most difficult thing you can imagine." Johnson urged corn maze operators to simply use common sense, treating a corn maze as any other commercial attraction. He also went on to add that operators should have fire extinguishers at the ready (McCallum M, 2008).

According to Waterman's Farm Market's website, some farming practices to make corn maze attractions safer are offered (Waterman, 2008). To help with fire proofing, they suggest planting the corn late, to ensure that it is green during harvest time. Adding nitrogen during the growing season will help keep the plant succulent longer than usual. The Waterman's caution about early season frost, which can rapidly dry a field make it flammable (Waterman, 2008).

Arson is the other major human factor that has led to the start of a fire in an agritourist attraction. As reported by the Sun Times, a 13 year old child was arrested after deliberately setting fire to a straw bale maze in which 150 people had to be evacuated (Unknown, 2002). As cited in the news story, parents frantically searched for children and many did not believe the reports of a fire. Fortunately, nobody was injured in this blaze. This apathy can only lead to increase, risk of injury and loss of life in a maze attraction. Deliberate arson fires at public assemblies are not a new phenomenon in the post 9/11 era. Wikipedia reports that terrorists choose the largest number of civilians to injure, often at "large outdoor festivals" ("History of Terrorism," 2011). John Hall Jr. in a publication by the National Fire Protection Association, writes that a percentage of arson fires are set as a deliberate act of harming people in a particular area (Hall J.R, 2007). The United States Fire Administration agrees, "Perpetrators strike with fire at buildings where people live, work, or socialize--causing injury, property loss, and death. Civilians and firefighters alike die in arson fires every year" (Attacking the, 2004). Arson fires at a place of public assembly have been a problem for fire prevention departments across the country for a long time. The recent proliferation of corn maze attractions and the very fact that the maze itself is a combustible is cause for alarm.

Industry Standards

In many parts of the country, where corn mazes are just starting, operators may not have many places to turn to for information on running a successful event. The local fire department could be a great starting point, as well as the numerous websites that have emerged which promote corn maze safety. One such website is provided by Hugh McPherson, "The Maze Master" (McPherson H, 2008). This site provides safety brochures and training information for employees. McPherson also sells public address kits to enable operators to address all the visitors in a corn maze at one time in the event of an emergency. At the time of this research, a search of available literature discovered no published manuscript that provides direction for all components of operating a corn maze. While common sense should prevail in the design and operations, it often does not. Parking vehicles on dry corn fodder is a perfect example.

In addition, a search of the uniform fire code revealed that the code does not address corn maze attractions specifically. To combat this, during 2011, in the Commonwealth of Massachusetts, the State Fire Marshal issued a memorandum to all department heads concerning corn mazes. Included in this memo are steps for fire, medical, addressing, and pre planning activities (Coan, 2011).

The Fire Marshals Association of Minnesota released a directive for corn maze activities in 2002, which gives guidance to; "establish minimum fire and/or life safety guidelines for the operation of certain theme parks in the State of Maryland commonly referred to as *"Corn Mazes."* (Barnard W, 2002) This Maryland directive established rules for occupancy load per acre, vehicle distances, fireworks, open flame, lighting and more.

In summary, the purpose of this literature review was to examine and summarize the research findings of others regarding corn maze fires. The search did not locate any published material directly written regarding ways to reduce the risks of corn maze fires. This research paper may be the first of its kind in this area and as such, the literature review leaned heavily on corn maze fires to date, the science of fire behavior, fuel types, weather, human factors, industry standards, and any other published data that contributed to the study of fire in a corn field.

Procedures

This applied research project uses descriptive research methodologies with literature review, three personal interviews and a field experiment to develop the final study results. The intent of these procedures was to obtain information and data from various sources in order to address the research questions previously noted and to develop recommendations. The procedures used to gather and prepare information for this project started with an extensive literature review. The initial portion of the literature review was conducted at the Learning Resource Center at the National Emergency Training Center in March 2011. Additional literature searches were conducted at the Albertsons Library on the campus of Boise State University, as well as the Ada County Public Library in Boise, Idaho. By reviewing the available literature, the author was able to gain insight into the research questions regarding the effects that weather, topography, fuel moisture and human factors will have on fire in a corn field.

The internet was utilized to locate information about corn maze attractions, and fires that have occurred in them. Key words and phrases for these searches included corn maze fire, corn field fire, corn maze safety, fire safety in corn field, agritainment, agritourism, fire marshal corn maze, and fire department corn maze. A secondary source for obtaining video information for use in this research came from the web site www.youtube.com. The main search phrases for videos about corn maze fires were corn maze fire, corn maze safety, corn field fire. Information found on the internet was used to answer all of the research questions.

Interviews were used extensively to gain enough knowledge to sufficiently answer the research questions. Interviews were necessary because of the lack of existing literature or experiments completed to help analyze fire in a corn maze. Because this research may be the first of its kind into the problem of fire in corn mazes, the author relied heavily on subject matter experts to apply their knowledge to the research questions. Three in depth interviews were conducted. In order for the participants to prepare for the interview, the questions and general subject matter were mailed to them one week before the interviews took place.

The purpose of the first interview was to learn about fuel models and decide what type of fuel model that a corn field would fit into, as well as other factors that would contribute to fire in a corn field. The interviews included fire behavior analyst Lance Okeson from the Bureau of Land Management (See Appendix B). These interviews took place in July 2010. The interview began with this hypothetical question "If you were assigned to predict fire behavior in a brown (cured) corn field, what process would you use to do it?" Okeson was then asked all of the research questions, 1-6 as listed in the introduction.

The second interview was to learn about corn as a plant, its growing cycle, and moisture content within the plant at harvest time. This interview was with Steve Gray, from Campbell Tractor and Implement Company of Nampa, Idaho. He was asked the following questions; What is the growth process from germination to death of a corn plant? Is there any way to determine the moisture content of corn leaves as they turn brown? Have you ever experienced a fire in a corn field, or heard of such? What fire risks are there in a corn field maze? In your opinion, will a mature corn field burn, and if so, under what type of conditions? See Appendix C for a list of all questions.

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

The third interview was conducted to learn about the industry of corn mazes and determine the level of safety built into corn mazes to safeguard against personal injury from fire and other hazards. This interview was with Brett Herbst, a corn maze developer and designer who operates numerous corn field mazes each autumn. Herbst was asked about the fire risks in corn mazes, will a corn field burn, and what human factors influence fire risks at corn maze attractions. He was also asked if fire safety is factored into his designs, like emergency egress points and quick exits. Another question posed was if he knew of any entity that produces safety information for fire departments or the general public in regard to corn mazes. The last line of questions covered his knowledge of any fires which have occurred in corn field mazes, or any situations where an emergency required patrons to exit a corn maze quickly. See Appendix D for a list of questions. Information from these interviews answered the research questions about all six of the stated research questions.

The best practices from each of these interviews could be used later, if needed, as part of the methodology in developing a corn maze safety program for the Boise Fire Department. Information gathered from the interviews was corroborated with additional data from various internet sites, publications and other research.

A simple experiment was conducted which consisted of the creation of a small plot of mature, cured corn plants. The purpose of this experiment was to observe the burn rate of corn plants and then compare this data to the expected fire behavior model chosen from Scott and Burgan’s work; “Standard Fire Behavior Fuel Models”. The corn stalks were placed into a table like framework with chicken wire attached across the top. The corn stalks were placed into the chicken wire in an upright fashion, standing approximately 48 inches high from the table top to the tip of the stalk. The spacing of the corn rows was 12 inches apart, and the plants were placed six inches from each other in their rows (See pictures Appendix E). A wind generating fan was set up approximately three feet from the corn plot to broadcast a wind across the corn stalks. It was observed by the researcher that the wind from this fan was turbulent and not consistent throughout the plot, so a second box type fan was added in an attempt to smooth out the air flow through the corn stalks. This worked with suitable results to achieve an average 8 mile per hour wind at the front edge of the corn plot. The fans were not running at the time of ignition, but were started 10 seconds into the experiment. Prior to starting the experiment, a complete spot weather forecast was obtained by a member of the Boise Bureau of Land Management office to obtain temperature, wind speed, and relative humidity (See Appendix F). Additionally, to verify the spot weather forecast, a local area forecast was obtained from weather.com using zip code 83709 (See Appendix G). To begin the experiment, a cotton rag was placed at the head of the plot, from table top level to ten inches in height. This rag was soaked in stove fuel and ignited. The subsequent fire from the soaked rag was sufficient to ignite the leading rows of corn stalks simultaneously (See Appendix E). Approximately ten seconds after igniting the rag, the wind producing apparatus was started to blow wind onto the fire. Forty seconds later, the fire reaches the end of the plot and the experiment ended. See Corn Field Fire Experiment at: http://www.youtube.com/watch?v=cP1Hp9gNruA This experiment directly influences the answer to the research question; will a mature corn field burn, and what type of fire behavior will exist?

There were certain assumptions and limitations made by the author of this research paper. The assumption was made that all participants in the interviews were honest and knowledgeable in their answers and understood the questions as presented. The author did not attach any qualifiers to any of the questions in an attempt to influence the answers. Limitations to the experiment are the size of the corn plot burned which would not represent the full ten foot average height of a mature corn field maze. The small fire size in the experiment did not allow for the fire to develop the intense heat and synergy that a real fire would, which would profoundly increase the rate of spread. The video produced and referenced is amateur at best, and was cut off during the filming sequence. The attempt to generate a ten mile per hour wind into the corn sample was flawed by the fact that the wind generation apparatus provides a circular, turbulent, inconsistent wind flow. A real wind blowing on the experiment plot would be consistent speed, and would blow across the plot at the same time, having a greater effect on fire spread than what is captured in the video.

Results

Using descriptive research methodologies, this author was able to obtain useful data to answer all six research questions.

Research question one: Will a mature corn field burn, and if so, what type of fire behavior exists?

The results from the interviews and the simple experiment all provided answers to this question. The interview with Okeson posed this question, "If you were assigned to predict fire behavior in a brown (cured) corn field, what process would you use to do it?" Okeson answered by saying he would first evaluate what part of the corn would carry the fire through the corn field (L. Okeson, personal communication, June 5, 2011). He identified that to be the corn leaves, and because they are brown and cured (meaning a low fuel moisture content) they would support combustion in the right environmental conditions. To find these conditions, he referenced the book "Standard Fire Behavior Fuel Models" to decide which fuel model the corn leaves fit into. In his opinion, corn leaves fit into model GR9 (109) "Very High Load, Humid Climate Grass".

This model indicates an extinction moisture content of 40 percent, which means that it will burn readily when the relative humidity is below 40 percent (Figure 1). This choice provides the remaining information about fire behavior. Two example photos of similar fuels are provided, with a description of the fuel, rate of spread and flame length. Okeson referred to the two charts at the bottom of Figure 1 to predict fire behavior. The graph on the left indicates rate of spread in chains per hour (66 feet), with different wind speeds. The second graph on the right indicates flame length in feet with different wind speeds.

Figure 1.

GR9 (109)

Very High Load, Humid Climate Grass (Dynamic)

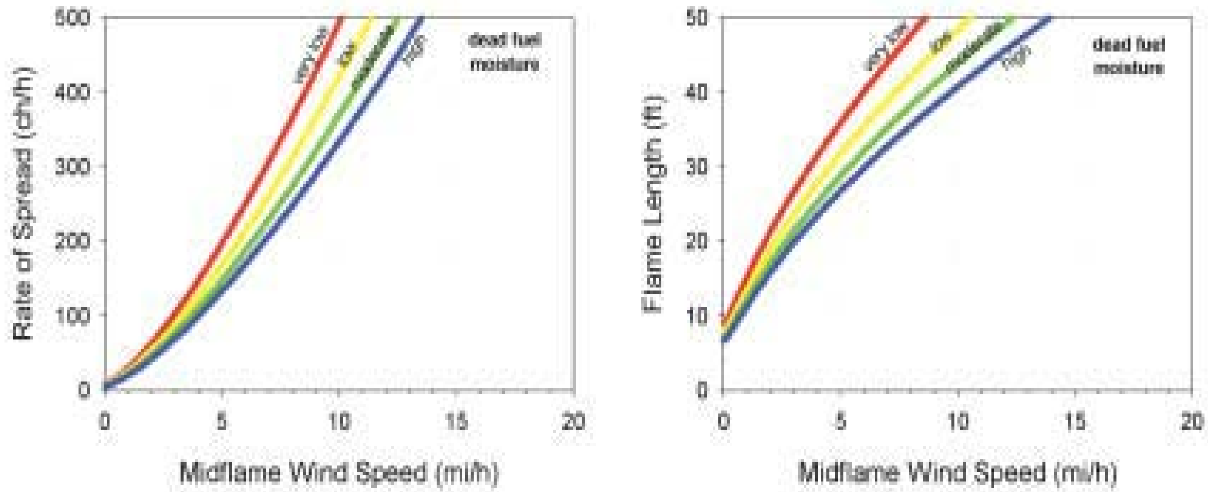
Description: The primary carrier of fire in GR9 is dense, tall, humid-climate grass. Load and depth are greater than GR8, about 6 feet tall. Spread rate and flame length can be extreme if grass is fully or mostly cured.

Fine fuel load (t/ac) 10.0

Characteristic SAV (ft-1) 1612

Packing ratio (dimensionless) 0.00316

Extinction moisture content (percent) 40



The interview with Steve Gray provided answers to this question as well. Gray pointed out that any brown agricultural crop will burn, under the right conditions (S. Gray, personal communication, June 14, 2011). He has witnessed fire in cured wheat fields, which burnt so quickly the responding fire department stayed out of its way. He has never heard of a fire in a standing corn field, but knows that burning corn stubble as part of an agricultural practice has been done in the past. Gray added that these crops will burn, but rain and damp weather make it almost impossible to burn a field correctly. As for moisture content, Gray is confident that if moisture content in the corn kernels at harvest time is around 15 percent, then the moisture of the dead leaves on the stalks must be below that.

The simple experiment confirms that a brown corn field will burn. The experiment shows tremendous fire spread in all directions, traveling four feet horizontally in just 8 seconds. This corresponds to a fires spread of 27 chains per hour. This corresponds to the rate of spread table in Figure 1. As the fire progressed through the experimental plot, almost 100 percent of the available leaves were burn, leaving only the green stalks. Flame lengths were 5 feet high, which is also consistent with the flame length chart in Figure 1. See Appendix E for the photo log of the experiment. The following hyperlink provides the video of the experiment: http://www.youtube.com/watch?v=cP1Hp9gNruA What is evident in the video is the volatility of the dry fuel in the first five seconds of video. After ten seconds, the wind generating fans were started, which appear to blow the flames out, instead of pushing them through the fuel. This is a major limitation of the experiment; only the first ten seconds provide keys to what the research suggests.

Research question two: What effect does weather have on fire in a corn field?

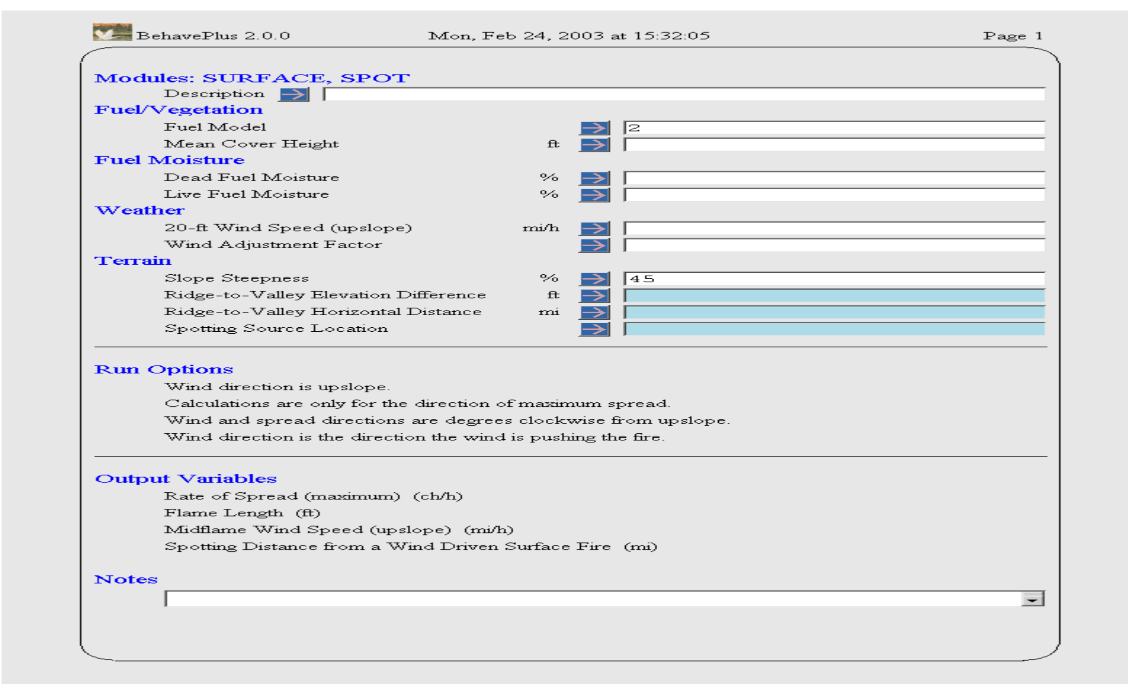
Okeson was asked this research question directly (L. Okeson, personal communication, June 5, 2011). He stated that weather is the most variable component of fire in any fuel type. It changes constantly and will drive fire intensity and direction. Fire in a given fuel can burn violently one day, and not support combustion the next day due to changes in weather factors. Because the corn leaves discussed in this research are cured, with a low fuel moisture, if the weather is such that the relative humidity is below 40 percent for corn, it will burn readily. Once this is established for a given day, Okeson said the largest contributing weather factor is the wind. The presence or absences of wind will change how a fire in corn will behave. Okeson referred to the rate of spread and flame length graphs in Figure 1 to reiterate that the fire simply doesn't move across the ground until the wind is factored in.

The experiment provides data to answer this research question. See Appendix F for the fire weather spot forecast just minutes before the experimental burn took place. Appendix G provides weather from weather.com to verify the temperature, relative humidity and wind speed. The temperature was 90 degrees Fahrenheit, relative humidity was 26 percent and wind speed at the fuel prior to starting the experiment was approximately 3 miles per hour.

Research question three: What effect does topography have on fire behavior in a corn field?

Okeson stressed the important role that topography plays on fire behavior in any fuel type (L.Okeson, personal communication, June 5, 2011). He stated that a steep slope will allow the fire to burn quickly because gravity allows the flames to preheat and conduct heat to the adjacent fuels easily. He said that the sophisticated fire prediction software “BEHAVE” used by federal fire managers always factors topography into the equations (See Figure 2). In addition to the slope, topographical features like canyons and ravines play a strong role in fire behavior. Features like these can either block the wind, or increase its turbulent effects on fire behavior. Okeson added that even rolling terrain, which is found in the Pacific Northwest corn fields, could greatly increase winds and influence fire behavior.

Figure 2.



The interview with Brett Herbst provided another viewpoint (B.Herbst, personal communication, July 20, 2011). Herbst pointed out that he stays away from choosing corn maze locations that have topographical influences to them. This is primarily done out of consideration to the patrons who have to walk uphill to go through the maze. Many of these patrons are small children, or parents with baby strollers and even wheelchair bound people. It is his view that flat terrain is preferred over rolling or sloped fields. Herbst also avoids slope because when it rains on these fields, the water will gather in the lowest spot in the fields, making a mud hole that takes too long to dry out. Furthermore, the slick conditions on the ground also create fall hazards on slope, so he would avoid these fields altogether.

Research question four: What effect does fuel moisture have on fire behavior in a corn field?

The interview with Okeson provides answers to this question (L.Okeson, personal communication, June 5, 2011). Fuel moisture plays a critical role in fire behavior, especially in a grass type fuel model like corn. Referring to Figure 1, the colored lines in the rate of spread and flame length charts indicate different levels of fuel moisture, and show graphically how that will change fire behavior. Very low fuel moistures are shown on the red graph line, and high fuel moistures are shown in purple. Okeson made note of these graph lines to answer this question. He used the following illustration; looking at the flame length table in Figure 1, a fire burning in a corn field with very low fuel moisture (3 percent) with a 9 mile per hour wind would give off a predicted flame length of 50 feet. The same corn burning with a high fuel moisture content (12 percent) would require a 14 mile per hour wind to generate the same flame lengths. He predicted rate of spread in the same fashion. Corn with a very low fuel moisture and a ten mile per hour wind would burn at 475 chains per hour. (31,350 feet per hour or 5.9 miles per hour) If that corn had a high moisture content of 12 percent, the ten mile per hour wind would move the fire at 300 chins per hour (19,800 feet per hour or 3.75 miles per hour).

According to Okeson, it's all about fuel moisture and wind. If it rains, and the fuel takes on that moisture, there will be no fire risk. On the other hand, if it rains and the temperature soars to 85 degrees with a strong wind and dries the fuel back down to a low fuel moisture, the fire risk is severe. Unfortunately, he said, this drying out process would take one hour or less for cured corn leaves.

The interview with Steve Gray sets the framework for the author's assumptions about the actual fuel moisture of a dead corn leaf (S.Gray, personal communication, June 14, 2011). Gray was asked "Is there any way to determine the moisture content of corn leaves as they turn brown? The answer is yes, fuel moisture can be found by utilizing commercially available moisture measuring devices. One is a scale, which weighs the fuel wet and then reweighs it after it is oven dried. The other type is a hand held device with electrical probes, which when inserted into a leaf or twig, will measure electrical resistance between the two electrodes and provides moisture content. According to Gray, this would be the most scientific method, but also the most cumbersome for field work. The easiest, in his opinion is to make the assumption that if the corn kernel moisture is 15 percent, and the kernel is where the residual moisture stays after plant watering stops, then the brown leaves on the outside, subjected to the sun, wind, and air would have a lower moisture content. Okeson agrees with this assumption, but adds that in his field work, if a plant is brown it is cured and no longer growing and therefore classified as having a dead fuel moisture content below 30 percent.

Based off a correct assumption that brown corn leaves have a moisture content below 30 percent, the experiment would verify the flammability of cured corn leaves. It is of particular interest that the cornstalks used in the experiment were green, pliable, and produced water droplets when squeezed. The corn leaves on the other hand, were pliable, but produced no visible moisture when squeezed.

Research question five: What are the fire risks of a corn field maze?

Okeson relates his fire knowledge to a fire in a corn maze. He is quick to point out the fact that a corn field full of children if under the right circumstances i.e.: wind above 5 miles per hour and a brown corn field, would likely result in the loss of life. The factors contributing to loss of life would be the rate of spread of the fire and the difficulty getting out of the maze. According to the rate of spread graph in figure 1, if a fire starts in a corn maze with winds less than 5 miles per hour, no catastrophic fire behavior is predicted. This stance is backed up by reference to the rate of spread and flame length charts.

The other risk in a corn maze fire is the dense, acrid smoke conditions that would develop at ground level, intensifying with stronger winds. Okeson said he includes a smoke management plan when he writes a prescribed fire burn plan, not because of its unsightliness to surrounding communities, but to the health hazards that it creates. According to Okeson, if a fire was burning in a corn field maze with winds at 20 miles per hour or greater, the smoke would lie down horizontally, thereby choking people downwind thus slowing their exit, creating panic and obscuring vision.

Steve Gray has no experience with fire behavior forecasts, or how people react to situations (S. Gray, personal communication, June 14, 2011). He was asked what are the fire risks of a corn maze, and he offered the following. First, he believes that corn may not be dry enough to burn in some localities. In the Boise area, this may not be the case, with harvest in September and corn maze activities in October through November, but in other regions, the corn may still be green in autumn. Secondly, he adds that if a corn maze was built and being used when the leaves were brown, there could be risk to the public. Based upon what he saw in the agricultural fields of wheat, "people would never be able to out run those flames".

Research question six: What human factors are associated with fires in corn field mazes?

Because of his time on the job as a fire behavior analyst, and fire fighter before that, Okeson pointed to arson and unintentional fire starts as the most likely human factors. In his experience, arson plays a large role each year in wild fires being started. Although he cannot imagine a person purposefully setting fire to an occupied corn field maze, he would not rule it out (L.Okeson, personal communication, June 5, 2011). The more likely scenario, in his mind, is an unintentional fire started by carelessness around the corn maze. Smoking and the operating of mechanical equipment were the two that struck him as most probable. The other normal causes of wild fire such as, electrical lines falling down in a wind storm, lightning, could cause a fire, but they are not human factors.

The interview with Brett Herbst assisted greatly with this research question (B. Herbst, personal communication, July 20, 2011). Herbst was asked what human factors influence fire risks at corn maze attractions. Herbst was quick to point out that with ten thousand visitors, the operator will get all kinds of people doing all kinds of things. His experience has mostly been with smoking, and enforcing that rule. Although most people follow the rules when they line up in the main activities areas, once they go into the maze, something triggers an instinct to smoke where people won't notice. In his opinion, this is the worst place to discard a lit cigarette or match because the fire would go unnoticed longer than if in the main areas. He also noted that some maze operators light warming fires in pits around the entrances of the mazes for ambiance. He believes this has to be done with caution. If the corn is green and not posing a fire hazard, campfire pits are ok. On the other hand, if the weather has been warm and the corn is brown, he will not allow campfires of any type.

Herbst was asked if fire safety is factored into his designs, like emergency egress points and quick exits. He noted that his function is about design and layout of the maze to meet customer requirements (B. Herbst, personal communication, July 20, 2011). Safety features are the responsibility of the operator of the maze itself. During this interview, Herbst answered the questions at the start very straightforward and off the cuff. As the authors questions about fire and safety became the topic of conversation, his answers were not as forthcoming.

Discussion

The purpose of this research is to identify the fire risks of a corn field maze and develop a prevention plan for the hazards associated with corn field maze attractions. The proliferation of corn field mazes in the Boise and surrounding areas are creating a “not if, but when” scenario. The research study and accompanying literature have made it clear what the fire risks are, how corn fields burn and why, and some basic fire prevention opportunities have come to light. As discussed as part of the EACRR course, the five E’s of prevention are Education, Engineering, Emergency Response, and Enforcement (Executive Analysis, 2011). The following discussion will make these opportunities clear.

Will a corn field burn?

The first point to be made from the research done is that a cured corn field will burn. Okeson knew that without having to witness it firsthand in the experiment. He applied the science from the other grass fuel models and calculated fire spread and flame lengths. Steve Gray has witnessed corn stubble on fire and wheat fields ablaze, and was able to conclude that standing corn, if it’s in the mature cycle of its life span would most likely burn (S.Gray, personal communication, June 14, 2011). Both men concluded that dangerous fire behavior would exist in the presence of dryness or high winds. Findings from the literature review reinforce this answer. Anderson (1992) states:

> 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 (including corn), that have not been harvested can be considered similar to tall prairie and marshland grasses.

It is important to note that a mature corn field can be as tall as 12 feet.

Scott & Burgan (2005) developed the book for estimating fire spread and flame length, in which they predict extreme rates of spread and massive 50 foot flame lengths for the corn field fire with high winds. This prediction is congruent with works done by Anderson (1992) and Okeson (2011).

The author's simple experiment shows that cured corn, at 90 degrees and 26 percent humidity will react violently as it erupts into flames. The rate of spread in the experiment matches that of what was predicted.

With the knowledge that a corn field can burn as violently as other wild land fire fuels, the opportunity for educating both patrons and corn maze operators about the risks has presented itself. Emergency responders may need to be trained as well, because some remain skeptical that a cornfield would burn, and may underestimate the extreme fire behavior possible.

Fire risks in corn mazes

The research work revealed similar trains of thought as to the risk of a fire starting in a corn field maze. Okeson's take on fire in a corn maze is the smoke conditions that would drive patrons into a panicked frenzy if enough of it was present (L. Okeson, personal communication, June 5, 2011). The choking hazard and reduced visibility would make it difficult to navigate out of the field, if one were lucky enough to know where they wanted to go in the first place since there may not be fire exits identified. A fire could possibly be managed during a calm day, but based upon his utilization of the fire prediction methodology; Okeson suggests that winds over 5 miles per hour would change things for the worst. Gray based his input on his own eye witness account of a grain field that erupted in flames, saying the fire crew stood by because of the "dangerous, fast moving flames."

The risk to firefighters themselves should also be noted. The literature review described the South Canyon Fire in 1994 as a perfect example of fire fighters being overrun in an environment of wind, fire, smoke, and uncertainty. (Butler et al., 2009) Goodson (2003) states that situational awareness plays a key role when fire fighting under adverse conditions. Heavy smoke, noise, obscured vision are normal environmental factors during extreme fire situations (L. Okeson, personal communication, July 20, 2011).

To put fire spread rates in perspective, according to the elite feet website, the world record marathon pace was twelve miles per hour (Brasta P, 2008). Most people walk at 3 miles per hour and jog around 6 miles per hour. Under ideal conditions, with good visibility and footing and the knowledge of exit routes, most people may escape a corn field fire. However, it is the authors opinion that because of the effects of the fire itself, smoke, noise, panic, and the lack of pre-defined exits, egress time for most people would likely increase.

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

The fire service has not been completely off the radar about the risk of fire in corn field mazes. In 2002 The Maryland Fire Marshal issued "Minimum Life Safety Guidelines for Corn Maze Amusement Attractions in the State of Maryland." (McCallum M, 2008). They include 13 provisions that are still in effect in that state. (See appendix H.) Roger Johnson, the Indiana State Fire Marshal, advised corn maze operators to use common sense and common safety rules. "A cornfield fire is about the most difficult thing you can imagine," he said. "A fire in a corn maze could be tragic and have monumental effects." Rogers went on to recommend something not on Maryland's list: Have fire extinguishers handy (McCallum M, 2008).

Bruce Waterman, who operates Waterman's Farm Market near Indianapolis, offered some advice to farmers on ways they can make corn mazes more fireproof and safer:

> "Plant it late," he said. "Make sure it's green in October." Last year, he planted a 114-day corn variety on June 17 and applied 140 pounds of nitrogen fertilizer to assure the corn would be succulent during October, the big maze month for the market. "For folks farther north – across the upper Midwest, Northeast and Canada – freezing is a problem," he said. Freezes can occur already in mid-September and the standing corn leaves will dry quickly. "Be careful," he said. The Waterman's have five mazes. In each one, the design and construction is geared to safety and to keeping his insurance agent happy.
>
> "Work with your insurance carrier," he said. "Don't lie and don't cheat."

The Waterman's create maze paths using a tractor and tiller that incorporates residue and make a rut-free, stalk-free path. Paths are cut early and seeded with grass seed that is mowed like a lawn at maze time. "It provides a better surface if it rains," he said. The five mazes vary in size. A small one is designed for the 10,000 school kids from kindergarten to second grade who visit each fall. That maze is simple, with no path choices. "They just go through and come out," he said. That generates enough excitement for little kids without inciting fear or terror. Another small maze, with some choices, is designed for older children. A third maze is “complicated enough that when my son cut it for me, he got lost.” The fourth is six acres, last year following a complicated Chicken Little design, cut with a riding lawn mower following a walker toting a backpack computer and following GPS coordinates (McCallum M, 2008).

The fire risks boil down to no exits, heavy incapacitating smoke, panic, and fast moving flames. Although this seems like a no-win situation, the best defense may be a strong offense. In this case, the fire department is well positioned to take a proactive step in enforcing the provisions of the uniform fire code that apply to all jurisdictions. Statewide and local ordinances could also be enacted to facilitate stronger enforcement. The implications to the Boise Fire Department are another opportunity to promote fire safety in a previously neglected market.

Weather

Okeson provides the textbook answers to the effect of weather on fire behavior in corn fields (L. Okeson, personal communication, June 5, 2011). His interview revealed that weather dictates fire behavior more than the effects of topography or fuel moisture. Simply stated, if it rains and the relative humidity is high and the fuel moisture is therefore high, there is no fire danger. But wait for an hour, with the sun shining and a wind blowing and the fire danger is right back on the table. Okeson points out that when he writes a fire plan, he includes a “window” of time in which fire behavior will be optimum for achieving the goals of the prescribed fire. For instance, if the prescribed fire plan is to burn off 100 percent of the cheat grass in a meadow, Okeson will predict the optimum hours in the day for that to occur. The inputs to this prediction are temperature, wind, slope, fuel moisture, relative humidity and fuel type. The outputs for this prediction are a window of time, in which the fire will burn with the greatest intensity to engulf 100 percent of the available cheat grass. This window may be from the hours of 1200 till 1700 hours, or it could be as short as 1500 to 1700, depending on the input values.

NWGC (1994) support this notion, as describing weather as the most variable influence to fire behavior. For a given fuel, compared from one day to the next, the topography does not change, nor does the fuel moisture levels, but the weather can and will. The changes in weather are variable day to day, and tend to have the greatest impact on fire behavior (Introduction to Wild, 2006).

The weather played key role in the experiment. Because the weather was prime to support combustion, relative humidity of 26 and air temperature of 90 (low relative humidity and high temperature) the experiment was a success and a positive influence to the research. A limitation of this design was to test the opposite of good weather, and choose conditions of low temperature and higher humidity. This would serve to show the relationship between the two weather conditions on the same fuel.

Of particular importance in weather is the role of wind on fire behavior. As was mentioned by Okeson, Anderson (1992) and Scott& Burgan (2005), wind is the deal maker. If the wind is present, it will fan the flames easily through this perfectly spaced fuel. If it is not present, the fire will still burn, however at a much slower pace and give time for people to take notice and warn others of the dangers. If it is present in high quantity, like 20 miles per hour, the picture becomes grave as rate of spread and flame length reaches a point where nobody could escape. Wind was noted in the experiment at 3 miles per hour, and played a significant role in the immediate consumption of all the first 4 feet of corn stalks. If a person was to predict fire behavior in a corn field, weather would need to be the major focus. The unpredictability of weather factors make it a candidate to include in a fire prevention plan for corn maze operators.

Topography

Of the three factors effecting fire behavior, topography is the most constant, and based on this study, does not influence corn fields to a great degree. This is due in part to the fact that cornfields are typically not planted on a slope, and secondly, those fields would not be first choice for the corn maze operator. Okeson helps with this by stating that it is not the lay of the land of the cornfield itself, but the topography of the surrounding areas which would influence a fire in the corn maze (L.Okeson, personal communication, June 5, 2011). A maze set up in between two steep canyons may exhibit turbulent winds that will affect the fire behavior. Steve Gray notes that it is difficult to successfully plant corn on terrain with slope because the water given to it will not stay on the corn long enough to water it (S. Gray, personal communication, June 14, 2011). Brett Herbst adds that corn mazes are not usually put in on hillsides because of the water runoff, drainage and footing problems associated with them (B. Herbst, personal communication, July 20, 2011).

Topography was included in this report because of its role in wildfire, being one of the three factors that determine fire behavior (Goodson, 2003). At the completion of the study, it is now apparent that while topography would play a role in fighting a corn field fire in the right geographic situation, its effects on predicting fire risks in corn maze fires is minimal.

Fuel moisture

The interview with Okeson provided the necessary insight into fuel moisture. Fuel moisture plays a critical role in fire behavior, especially in a grass type fuel model like corn. The mix of wind and fuel moisture drive rate of spread and flame length. The example of low corn fuel moisture and a ten mile per hour wind gave a rate of spread of six miles per hour. This is an extreme rate of spread.

Okeson makes his main point about fuel moisture in corn leaves when he described the one hour time lag for a wet fuel from rain to dry out and be ready to burn again (L. Okeson, personal communication, June 5, 2011). This fact alone can almost negate the effects of a wetting rain on fire danger.

In any study, it is good practice to avoid the use of making assumptions. The main assumption in this research was that a brown corn leaf had a moisture content less than 30 percent and therefore would be considered a fully cured fuel. Gray agrees with Okeson that a brown corn leaf would have less than 30 percent moisture. Gray uses kernel moisture of 15 percent at harvest time, to conclude that the brown leaves on the outside are lower than that.

Others provide solid data to support this. Herb Bucholtz & Mike Allen support this finding with facts for storing corn for silage (Allen H., 1997). Silage storage is the process of chopping up standing corn and storing it for later use. They note that at 30 percent dry matter; the corn is ready for storage. Wheaton (1993) concurs, writing for the Missouri Extension office, “corn should be harvested for silage…but before the leaves turn brown and dry” (Wheaton H, 1993). This statement verifies that even before the leaves turn brown and dry, the moisture content of a chopped up whole plant is below 30 percent.

Based off a correct assumption that brown corn leaves have a moisture content below 30 percent, the experiment verified the flammability of cured corn leaves. It is of particular interest that the cornstalks used in the experiment were green, pliable, and produced water droplets when squeezed. The corn leaves on the other hand, were pliable, but produced no visible moisture when squeezed. The moisture point at which a corn leaf turns brown is unknown at this time;

further research could reveal this information. What is important is that when the leaves are brown, they are ready to burn.

These factors related to fuel moisture make it a candidate to include in a prevention plan for maze operators.

Human factors

Okeson pointed to arson and unintentional fire starts as the most likely human factors regarding fire in a corn field (L.Okeson, personal communication, June 5, 2011). Smoking and the operating of mechanical equipment were the two that struck him as most probable. Brett Herbst said that his experience has mostly been with smoking and fire pits used for lighting and mood (B. Herbst, personal communication, July 20, 2011). The literature review supports these valid concerns. Of the 13 rules enacted by the Maryland Fire Marshal, five of them have to do with fire in and around the corn maze. (See Appendix H) No smoking in the corn maze is one of the rules, and follows industry standards in combustible environments. No fireworks, no flame emitting devices, no parking, and creating fire lanes are the others aimed at reducing the human factors associated with fire. The tragedy in Pennsylvania points to an example of an unintentional, but completely preventable fire in a corn maze. Using the corn field for a parking area makes sense, but common sense must prevail.

What is missing in this industry is a common set of nationwide guidelines to help operators and the patrons of corn mazes understand the risks. The fire department plays the role in this case, being the messenger for safe corn maze operations. Fire departments educate fireworks consumers and stand operators every year to the dangers and safe practices of fireworks. The same could happen in the fall when agritainment season begins. The presence of the fire department at a corn maze inspection similar to a firework stand inspection would create a cooperative approach to enforcement of the applicable codes for corn maze operations.

Recommendations

The vision statement of the Boise Fire Department reads; "As one of the nation’s premier fire departments, our members are responsive to the dynamic needs of the community. We are innovative leaders in our profession, dedicated to caring for each other. Protecting lives and property is our contribution to making Boise the most livable city in the country." (Doan, 2009)

The following recommendations are intended to assist in the process of meeting these goals through the risk reduction process.

- Form a committee of department members and community stakeholders to discuss the findings in this research paper, focused on developing an educational campaign aimed at maze operators and the general public. Allow the committee to determine the level of organizational and community support.
- Work with Boise Fire prevention to develop a standard corn maze inspection plan including a form to be used in the same manner as a firework stand inspection.
- Educate members of the fire department on the risks associated with corn maze attractions, and proper reporting procedures in NIFRS.
- Incorporate existing safety provisions of others into a safety pamphlet for distribution at schools, festivals, fire stations and corn maze attractions.
- Work with federal agencies to develop a pocket guide for corn maze operators and fire prevention bureaus to predict days where extreme fire behavior would exist, and urge operators to take precautions.

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

Further research is necessary into the logistics of implementing this list of recommendations. These committees require time and human resources in order to be successful. Funding streams from public/private partnerships could be forged to offset costs associated with the development of educational materials. Additionally, not every jurisdiction in the country will find this research to impact their community. However, even those communities that have green corn mazes with no inherent fire risk could benefit from the publicity of a fire department walk through safety inspection and pre plan.

References

Agritourism. (2011, August 14). Retrieved August 25, 2011, from Agritourism: http://en.wikipedia.org/wiki/Agritourism#cite_note-0

Allen H., Bucholtz H. (1997). *Frost on Corn for Silage* (fact sheet #4). Retrieved August 20, 2011, from msu.edu Web site: http://www.ipm.msu.edu/pdf/HarvCorn&Silage.pdf

Anderson H.E. (1982). *Aids to Determining Fuel Models for Estimating Fire Behavior* (1st ed., Vol. 1). Ogden, UT: Intermountain Forest and Range Experiment Station.

Andrew C. (2003, October 19). *Brush Fire Scorches 30 Cars*. Retrieved July 30, 2011, from Lancasterfire.com Web site: http://www.lancasterfire.com/amazing_maize.htm

Attacking the Violent Crime of Arson. (2004). Washington, DC: Department of Homeland Security.

Barnard W. (2002, September 23). Corn Maze. Message posted to All State Fire Marshalls, archived at http://www.bitwiselogic.com/clients/fmam/CornMaze.aspx

Brasta P. (2008, July 22). *How Fast Can Humans Run?* Retrieved August 1, 2011, from elitefeet.com Web site: http://www.elitefeet.com/how-fast-can-humans-run

Butler B.W., R.A. Bartlette, L.S. Bradshaw, J.D. Cohen, P.L. Andrews, T. Putnam. (2009, July 3). In Rocky Mountain Research Station (Ed.), *Fire Behavior Associated with the 1994 South Canyon Fire on Storm King Mountain, Colorado*. Retrieved August 3, 2011, from Colorado Firecamp Web site: http://www.coloradofirecamp.com/south-canyon-fire/summary-authors.htm

Coan S. (2011, June 1). Corn Mazes. Message posted to Department Heads, archived at http://www.mass.gov/Eeops/docs/dfs/osfm/advisories/2011/20110601_corn_mazes.pdf

Doan, D. (2009). *Boise Fire Department* [Brochure]. Boise, ID: Author.

Executive Analysis of Community Risk Reduction (2nd Ed.). (2011). Emmitsburg, MD: FEMA.

Executive Analysis of Community Risk Reduction (2nd ed., Vol. 1) [EACRR]. (2011). Emmitsburg, MD: FEMA.

Goodson C. (2003). *Wildland Firefighting for Structural Firefighters* (4th ed., Vol. 1) (C. Brakhage, Ed.) Stillwater: Board of Regents, Oklahoma State University.

Hall J.R. (2007). *Intentional Fires and Arson*. Quincy, MA: National Fire Protection Association.

HelloMetro, Inc. (2011, June 14). In Inc. HelloMetro (Ed.), *Boise Census*. Retrieved July 1, 2011, from HELLOBOISE.com Web site: http://www.helloboise.com/census.cfm

History of Terrorism. (2011, March 11). Retrieved July 12, 2011, from History of Terrorism Web site: http://en.wikipedia.org/wiki/History_of_terrorism

Idaho Department of Commerce. (2011, August 13). *Explore Idaho*. Retrieved August 13, 2011, from Visit Idaho Web site: http://www.visitidaho.org/

Introduction to Wild land Fire Behavior. (2006). Boise, ID: Author.

McCallum M. (2008, March 21). In Mikillovich M (Ed.), *Fire the Ultimate Nightmare for Corn Maze Operators*. Retrieved August 12, 2011, from Vegetable Growers Network Web site: http://vegetablegrowersnews.com/index.php/contact

McPherson H. (2010). In Hugh McPherson (Ed.), *Corn Maze Safety Kit*. Retrieved August 2, 2011, from Maize Quest Web site: http://www.cornmaze.com/Pages/Corn%20Maze%20Cornfield%20Maze.aspx

National Wildfire Coordinating Group. (Ed.). (1994). Unit 8- Fuel Moisture. *Intermediate Wildland Fire Behavior* (pp. 191-201). Boise, ID: National Interagency Fire Center.

National Wildfire Coordinating Group. (Ed.). (1994). Unit 8- Fuel Moisture. In *Intermediate Wildland Fire Behavior* (pp. 191-201). Boise, ID: National Interagency Fire Center.

Parker, T. (2011, January 3). *Economic Research Service*. Retrieved August 4, 2022, from USDA Fact Sheet Web site: http://www.ers.usda.gov/statefacts/ID.HTM

Perry D.G. (1990). *Wildland Firefighting* (2nd Ed.). Bellflower, CA: Fire Publications.

Scott J.E., Burgan R.E. (2005). *Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model* (1st ed., Vol. 1). Fort Collins, CO: Rocky Mountain Research Station. (Original work published 2005)

Stephens S.L., Ruth L.W. (2005). Federal Forest-Fire Policy in the United States. In S. Stephens & L. Ruth (Eds.), *Ecological Applications* (15(2), 2005, pp. 532–542). Berkeley, CA: Ecological Society of America.

Taylor G.R. (2001). *Contribution of the Agribusiness Industry to Idaho's Economy* (Bulletin 836). Moscow: University of Idaho.

Unknown. (2002, October 10). In Sun Times (Ed.), *Arson was last Straw*. Retrieved May 22, 2011, from Firehouse.com Web site: http://www.firehouse.com/forums/archive/index.php/t-41883.html

USDA Economic Research Service. (2002). *Farm characteristics (Idaho Fact Sheet)* (Idaho Fact Sheet). Washington, D.C: Author.

Waterman B. (2008, September 22). *Corn Maze Safety*. Retrieved June 30, 2011, from Waterman’s Farm Market Web site: http://vegetablegrowersnews.com/index.php/magazine/article/Fire-The-Ultimate-Nightmare-for-Corn-Maze-Operators

Wheaton H. (1993, October). Corn Silage. In University of Missouri Extension (Ed.), *Department of Agronomy* (G4590). Retrieved July 6, 2011, from extension.missouri.edu Web site: http://extension.missouri.edu/p/G4590

Wiki. (2011, August 14). Retrieved August 25, 2011, from Agritourism: http://en.wikipedia.org/wiki/Agritourism#cite_note-0

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

Appendix A

Anderson's Fuel Model 3

Photograph 6. Fountain grass in Hawaii

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 of 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.

Photograph 7. Meadow Foxtail in Oregon

Photograph 8. Sawgrass in the Everglades Florida

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

Appendix B

Interview Questions for Lance Okeson

Lance Okeson
Fuels Program Lead
Boise District Bureau of Land Management
3948 Development Avenue
Boise Id, 83705
208 384 3486
lokeson@blm.gov
Interview Dates June 5 & July 6, 2011

1. **What is your job title?**

   I am the program lead for the fuels department in the Boise District.

2. **What are you job duties?**

   I provide information to the fire suppression overhead (supervisors) about fuel loads, fuel moistures, tons per acre, growth, and I write prescribed fire burn plans. I also conduct prescribed fire burns because of my qualifications as a type 1 burn boss.

3. **How long have you been working for the BLM?**

   Over 20 seasons, I lost count.

4. **How can you decide if a wild land fuel is dry enough to burn?**

   There are a few ways, but the obvious one is to look at the color. In our region, if it's cured, I mean dead and brown, it's ready to burn. The science part of it would be to know what its dead fuel moisture is. If it is below 30 percent, we say that it is fully cured, and therefore will burn. Of course, you have to figure the weather into the equation, if it's raining, it won't burn, but seriously, you have to take the humidity into account. If the fuel has moisture of extinction of 15 percent, then the relative humidity has to be below that for it to carry fire. If the humidity is over that, it may burn, but it will not spread. We also call that the probability of ignition, or pig, and it will tell us (from a chart) when the fuel is dry enough to carry fire and burn readily.

5. **If you were assigned to predict fire behavior in a brown (cured) corn field, what process would you use to do it?"**

   Well, you said it's brown, so I am guessing that it has cured. Corn would be like some other plants we have, like cat tails. What you do is you choose a fuel type from the fuel models book, based upon your experience. So looking at the book, I would classify corn as a GR9, or grass fuel high load, and tall fuel. Once you choose a model, you go to the graph below it to see what fire behavior is predicted. I see for a GR9, it has a steep graph, which tells me that it will have a fast rate of spread with little wind. It also says that with no wind, it won't move around much. Flame lengths are predicted also, and they get huge for grass, fifty feet long with a 15 mile per hour wind. I imagine that corn is tall, like ten feet, so the flame lengths could be longer than fifty.

6. **In your opinion, will a mature corn field burn, and if so, what type of fire behavior exists?**

   Oh yes, definitely, based on what we just did. There isn't much to guess at, these models are dead on accurate. You can get some variation in the prediction, but that's if the fuel is thick in one spot and thin in the other, but corn….that is like the perfect fuel bed. It's vertically and horizontally the same. Fire would rip through it, especially with a wind.

7. **What are the fire risks of a corn field maze?**

   I have never even thought of that. Until you mentioned this, I have driven by them, and even gone to them with my kids when they were younger and never even thought of it. I would say now that if a fire started and had some wind on it, they could be a death trap. The fire itself would rip, but the smoke and ash would be nasty, you wouldn't be able to see. That could take out a lot of people in one shot.

8. **What effect does weather have on fire behavior in a corn field?**

   Weather is the deal maker. If it's humid and calm, there would be no risk for fire. But on the other hand, if it were a fire day with low humidity, wind and an unsettled atmosphere, that fire would rip. All the difference is in that wind… if you had a 20 mile per hour wind, and she was dry enough to burn, that thing would take off.

9. **What effect does topography have on fire behavior in a corn field?**

   Topo wouldn't do much, other than the regular effects of slope, which of course speeds things up. But the big thing would be corn out by the canyons, where the topo would channel the wind and blow it around. Fires are tough out there, the wind will dictate the fire, and you never know what you will get.

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

10. What effect does fuel moisture have on fire behavior in a corn field?

Well, remember when I said that the fuel has to be dead, at least below 30 percent moisture? That is the ticket, if the fuel moisture is above that, it won't burn. We can get the pig for the corn; it's the same for the other fuels in that model. That will tell us if and when it will burn, but fuel moisture is depended entirely on the weather so yes it does have a huge affect on fire behavior.

11. What human factors are associated with fires in corn field mazes?

Human factors like kids and stuff? Oh, I see, well for why a corn field would burn, I would say smoking would be the problem. Just like a lot of our fires out here, discarded matches from smokers actually start fires. But the other thing would be arson you know, some ******** doing it on purpose. I can't imagine that would happen, but you never know anymore. I suppose that lightning or a downed power line could do it too, those are the usual fire causes for us.

12. Have you ever witnessed or heard of a corn field fire?

No, and actually I never even thought of it until you called me. I can't believe that I have been at them (mazes) but never thought of it. I have burned a lot of wheat and it goes up like you can't imagine, so I bet corn would be a big show.

Appendix C

Interview Questions for Steve Gray

Steve Gray
Campbell Tractor and Implement
2014 N. Franklin Blvd
Nampa, Id 83687
208 466 8414
Interview date June 14, 2011

1. **What is your job title?**

   I am a senior manager, but I do mostly contacts with growers.

2. **What are your job duties?**

   Jack of all trades, but mostly I work with growers to get the most out of what we sell them in equipment. I help them with new equipment features.

3. **What is the growth process from germination to death of a corn plant?**

   Well, the plant is seeded and of course germinates quickly; the whole plant actually grows very fast. It goes through stages, that the farmers use to gauge how well it will produce. Like the stalk time, tassel time, silk stage, dent stage, black stage. It's all just knowing what stage the corn is in to know how it is growing and what it needs for water, nutrients.

4. **Is there any way to determine the moisture content of corn leaves as they turn brown?**

   We don't usually care about brown leaves, because they turn soon after the water stops in September. The thing for us is the content of moisture in the kernel. That is what our combines measure to tell the farmer to wait or keep harvesting. You want the kernels to be 15 to 18 percent when you harvest. The machine will tell you that. If you wanted to know the moisture of the leaves, you can use a microwave to dry them out somehow, or a handheld….forgot the name…device to measure the moisture.

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

5. **Have you ever experienced a fire in a corn field, or heard of such?**

   No, I think they would be too green to burn good. I saw one in a corn stubble field once and man that thing took off. The fire crews just watched it burn, I think it would have out run them in their trucks. I have seen a wheat field burn, it was by accident but it goes up in a hurry. I bet if the field was dry, like in October or if it froze and then got warm, it could burn better.

6. **What fire risks are there in corn field maze?**

   I don't know if there are any, really. I guess you are asking about a dead field, and if the guy got out there and had a problem with his machine, it could catch fire. I don't know if the field would be dry enough during the maze season though. I haven't really noticed that. They run those things (mazes) right up until it snows sometimes.

7. **In your opinion, will a mature corn field burn, and if so, under what type of conditions?**

   I think a corn field could burn, but not until October, cause the water is still in the stalks till then, and I don't think you could get it to burn. I suppose that if it were dry and dead, you could get it to burn, but I have not ever seen it. Wind would make it got better, I would think.

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

Appendix D

Interview Questions for Brett Herbst

Brett Herbst
PO Box 367
Spanish Fork, UT 84660
801798 0596
Interview July 20, 2011

1. **What is your job title?**

   I am the owner of The Maize. I design and sell corn maze plans for customers worldwide.

2. **What are you job duties?**

   I design corn mazes, but farm and am on the phone a lot. I spend a lot of time talking to clients about designs and how to cut them.

3. **In your opinion, will a mature (brown) corn field burn?**

   I think it would. I have heard about some fires in corn fields, a maze that was getting set up and they parked cars on top of the corn stalks that were knocked down. Nobody got hurt, but it burnt up a lot of cars. Up in your area, the corn may get brown later in the season, but in a lot of places, it doesn't get that way until later in the fall.

4. **What are the fire risks of a corn field maze?**

   Risks? Oh well if you had a fire with people in the maze, you could hurt somebody, but I have never heard of this happening. The risks, for people getting hurt is from falls and slippery ground or twisted ankles. I see those almost every day, so we try to get the owners to flatten out the ground. They can till it up so people walking push it down and flatten the ground out. I don't see the fire thing, but I guess it could happen.

5. **What human factors influence fire risks at corn maze attractions?**

   Not sure of the question. Oh, like how a fire would start? You should know that as the fireman right? I deal with all kinds of people; you would not imagine the kinds of things that I have seen in the maze. People that smoke in the maze are the biggest deal, but I do that because the fire marshal usually requires it, but not everywhere. People go from where it says no smoking, and walk into the maze and light up a smoke out there. I suppose that is where the fire would come from. But what could start a fire is the fire pits that some places use to light up the entrances and isle ways.

It's cold in most places by October, especially at night and people like to hang around the fire and let the kids run around the maze. Some places have let people take lantern, the lit ones into the maze for lighting, but most places use flashlights.

6. **Is fire safety factored into his designs, like emergency egress points and quick exits?**

   Most places take care of that. Some of the big ones have people on platforms that watch the maze, but it's not a huge deal. I design it based on drawings or what I come up with and don't necessarily make a path for an exit. The operators are in charge of those details, if they want to or not.

7. **Do you know of any entity that produces safety information for fire departments or the general public in regard to corn mazes?**

   Yes, there are websites that have safe stuff for kids to do. I know that I have seen a safety kit that has stuff for people to do to stay safe. I don't know about the fire department and if they get it. Most of the fire marshals are looking for extension cords and stuff like that. I guess the fire department would be a good place for you to go and look.

8. **Do you have knowledge of any fires which have occurred in corn field mazes, or any situations where an emergency required patrons to exit a corn maze quickly?**

   I don't think you're going to get a fire in a maze. I mean, if there was one, people would notice, but I have not heard of any besides the one that burned the cars. That was just dumb to park cars on top of the tall corn. You should disk it up or till it to park cars on it. I have seen people leave a maze quickly when a huge rain storm hit one. People ran to their cars to wait it out. There is so much open space, it's not like a building, the mazes are very safe.

Appendix E

Photos of Experiment

Experiment setup device

Fire starts 0:00

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

Fire exploding 00:05

Fire reaches end of plot 00:36

Format changes have been made to facilitate reproduction. While these research projects have been selected as outstanding, other NFA EFOP and APA format, style, and procedural issues may exist.

Appendix F

Spot Weather

During Experiment

Date 9/11/2011

Location Boise, Idaho

Elevation 2776 ~~2792~~ Feet

Aspect N E S W

Exposure (Ridgetop, slope, etc.) Flat

Cover Type (As indicator of wind obstruction) ~~[illegible]~~ Corn

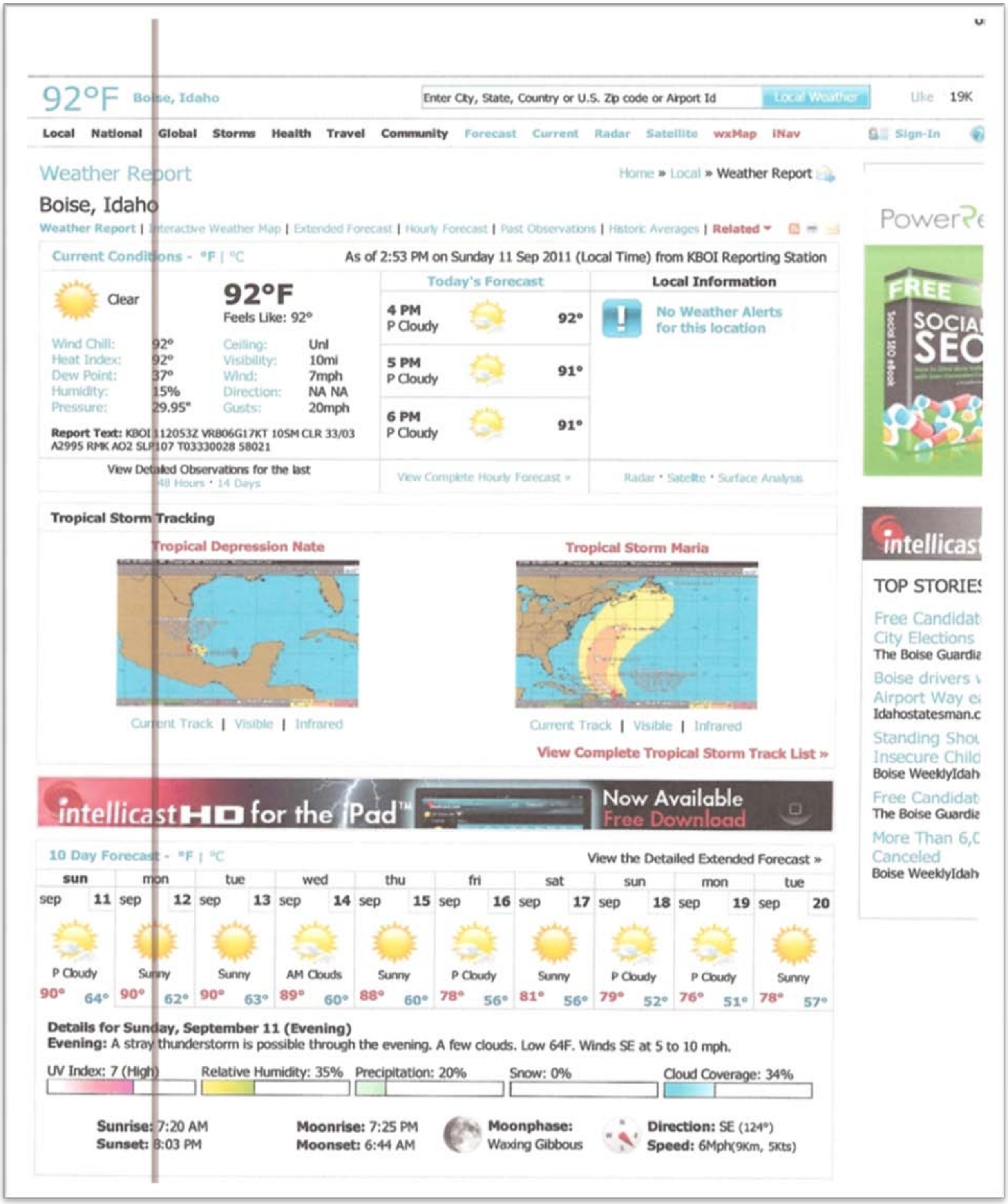
Stand Density (As indicator of wind obstruction) thick

Time (__ST)	Temperature (Degrees F.)		Relative Humidity (Percent)	Wind		
	Dry	Wet		Speed (M.p.h.)	Direction (From)	Characteristics and Comments (See instructions on cover)
1500	90°F	67°F	~~28~~ 31	3	110°	43° 34.391' 116° 17.413'
1515	90°F	65°F	26	3	110	Cumulus clouds 20% Cover
						WIND GUSTS AT 5 MPH

Appendix G

Local Weather Report

Prior to Experiment



Appendix H

Maryland's 13 Corn Maze Provisions

1. The operator must advise all employees of the fire and life safety guidelines.
2. The operator must provide safety instructions to visitors before they enter the corn maze.
3. At least two employees must monitor a corn maze during operation, at least one on an elevated platform at least 10 feet above the maze.
4. The local fire department must be notified and given the opportunity to prepare a "preplan" before the start of seasonal operations.
5. No devices producing open flame are allowed within a corn maze.
6. No smoking is permitted within the maze.
7. Not more than 200 persons per acre may be in a corn maze at any one time.
8. Motorized vehicles must not be parked within 75 feet.
9. A fire lane at least 10 feet wide must be cleared between a corn maze and structures or vegetation outside the maze.
10. After dark, visitors may only use flashlights to illuminate their travel through the maze.
11. A public address system – a bull horn or loudspeaker ¬– must be readily available to employees to assist them in making announcements to the visitors in the event of an emergency.
12. The entrance and exit from a corn maze must not be blocked or obstructed.
13. Fireworks must not be discharged within 300 feet of a corn maze.