The Tracer Ignition Minimization Tool (Legacy 10-374)

Abstract

Wildfires are a growing concern to military land managers throughout the country. Climate change, additional land use pressures and encroachment, and invasive species that encourage fire all contribute to an increasingly fire-prone military training environment. But because training is the primary ignition source on most live-fire installations, military land managers have some ability to mitigate the fire threat by constraining fire-prone training activities to lower fire danger periods. This can be accomplished at a gross level through the National Fire Danger Rating System (NFDRS), but a more precise accounting of fire likelihood that takes into account the specifics of military training and the complexities of military ignited fires is often desired to avoid over or under prediction.

One of the largest causes of military training ignited wildfires is the small arms tracer round. In this study, we used observations of fire ignitions in the laboratory to build predictive capacity related to the probability that a military tracer round coming to rest in *Megathyrsus maximus* (guinea grass) fuels will start a fire. We built a climate controlled wind tunnel that controls wind speed, temperature, and relative humidity. Fuels were conditioned in the wind tunnel overnight and were then subjected to an ignition device that mimics the effect of a tracer round coming to rest in guinea grass in terms of both temperature and duration.

This approach shows some promise in military applications. It is far more precise in predicting ignition probability than the NFDRS because it is related to the specific heat profile characteristics of the tracer round rather than a generalized model related to a hypothetical firebrand which behaves quite differently. It is also specific to the fuels into which the tracer round is fired, which may or may not be the case when using the NFDRS. These improvements allow land managers to reduce fire ignitions on training ranges without unnecessarily constraining military trainers.

Project Specifics

Description of geographic setting: The current data applies to guinea grass dominated live-fire ranges throughout the tropical Pacific, including Hawaii and Guam. However, the methodology can be applied anywhere to develop the relationships necessary to predict tracer ignition probability in any fuel type.

Principal Investigators:

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Partners:

Funding, support, and development

- **DOD Legacy Resource Management Program, Virginia:** Provided funding.
- **United States Army Garrison, Hawaii:** Provided support including sample collection (Michelle Mansker, Kapua Kawelo, Scott Yamasaki).

Technical expertise

- **Picatinny Arsenal, New Jersey.**
- **Colorado State University, College of Engineering** (Marcus VerMeer).

Service branch: Army

Project location: Schofield Barracks Military Reservation, HI (samples), Colorado State University (experiment location).

Installation size: Schofield Barracks 8,623 acres. USAGHI training areas ~185,000 acres.

Installation primary mission: Training.

Project dates: July 2010 to March 2012.

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Purpose/Need

Wildfire Trends

A host of factors is conspiring to make fire management ever more challenging in the coming decades including a hotter and dryer climate which makes fires more difficult to control, more likely to occur, and extends the fire season; encroachment issues which potentially make even small fire events a public relations issue; ever more rare species being protected by law which increases the likelihood of a fire triggering federal intervention or lawsuits; and invasive species colonization of training areas, many of which promote fire by increasing fuel loads and fuel continuity. Many of these factors are difficult or impossible to control at the installation level.

Ignition Control

Ignition prevention is a means of mitigating fire risk that is available to most land managers and, if implemented properly, can be highly effective. Small arms tracer munitions cause half or more of all ignitions on most military live-fire ranges. Better control of this single ignition source can dramatically reduce training related fire losses.

Approach

Our objective was to simulate in a highly controlled environment a tracer round coming into contact with dead vegetation. We achieved this by building a climate controlled wind tunnel within which temperature, relative humidity, and wind speed were regulated. We also built an ignition device that simulates the tracer round heat profile in terms of size, temperature, and duration.

The wind tunnel produced temperatures within 1° C, relative humidity within 1.5%, and wind speed within 0.045 m/s of the desired conditions. The ignition device used a servo motor to produce a highly replicable motion to bring a heated nichrome 80 wire coil into contact with the fuels for one second, the burnout time of a 7.62 mm tracer round such as the M62. The coil was manufactured to 7.62 mm in diameter and was heated via controlled electrical current. The temperature was measured by a thermocouple and was manipulated to within 10° C of the 1000° C target temperature.

Live and recently dead guinea grass (*Megathyrsus maximus*) fuels were collected from Schofield Barracks Military Reservation in Hawaii, shipped to Colorado State University, and dried and stored in a drying oven for the duration of the experiment. No samples showing signs of decomposition were used. We determined the surface-area-to-volume ratio for each batch of grass. We also determined the time lag, a measure of moisture response, for guinea grass.

Small samples of dead fuels in a standardized arrangement were placed on one of eight raised metal mesh bed. The mesh bed allowed air flow below the fuel bed as is observed in the field. Two baskets of fuels were placed in the wind tunnel as well to allow us to measure the fuel moisture. The fuels were conditioned in the wind tunnel for a minimum of 18 hours to ensure equilibrium with the conditions in the wind tunnel had been achieved.

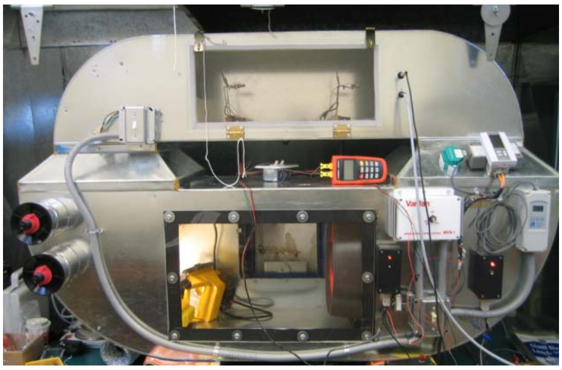
At the end of the conditioning period we used the ignition device to attempt to ignite each of the eight the test beds. Each repetition was videoed. Video editing software was used to make precise measurements of the length of time flaming and smoldering combustion were evident.

We defined an ignition as glowing combustion lasting 10 seconds or more from the time the ignition device left contact with the fuels. This definition has been applied in previous studies when small samples are used.

We used adaptive sampling to focus our efforts on regions of temperature, relative humidity, and wind speeds of interest while avoiding repetition of the experiment under conditions where the outcome is a foregone conclusion.

The data were analyzed to eliminate the possibility of effects due to test bed location in the wind tunnel and batches of grass. We used step-wise logistic regression to determine significant effects in our model.

We also developed a relationship between 20 foot wind speeds, the typical height at which wind speeds are measured, and ground level wind speeds, the height at which wind speeds were measured during the experiment. This avoids requiring users of the results to make special wind speed measurements at ground level.



The climate controlled wind tunnel.

Results

Experimental Results

The experiment resulted in a total of 719 repetitions. The stepwise selection method produced a model with two significant explanatory variables, fuel moisture ($p < 0.0001$) and wind speed ($p = 0.0127$), both of which are known from previous studies to affect ignition probability. We also ran backward and forward selection procedures to see if they would produce different models. Both resulted in the same model as stepwise selection.

The resulting model is in the form of:

$$P(IG) = \frac{e^{(5.4309 - 0.5968(FM) - 0.2897(WS))}}{1 + e^{(5.4309 - 0.5968(FM) - 0.2897(WS))}}$$

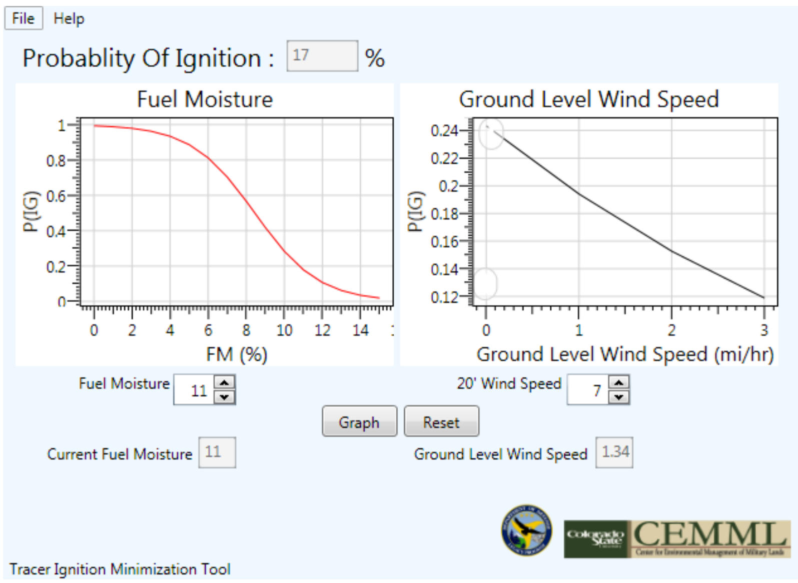
where *P(IG)* is the probability of ignition, *e* is t he irrational number 2.718, *FM* is the 1 hour fuel moisture in percent, and *WS* is the wind speed in miles per hour.

Fuel moisture has the strongest effect on *P(IG)* with wind speed having a smaller, but still substantial, influence. Contrary to some, but not all, previous studies, wind speed was found to have a negative effect on *P(IG)*. This may be due to the ignitions in our study being limited to the top layer of fuels. Previous work suggests that ignition sources buried deeper in the fuel bed are more likely to be positively affected by higher wind speed.

Our study displayed a 50% probability ignition threshold for fuel moisture of 8.6%, considerably lower than previous studies, likely due to the short duration of the tracer heat profile which does not allow moisture in the fuels to be driven off by the ignition source.

The TIM Tool

We encoded the *P(IG)* equations into a computer interface allowing a user to enter the fuel moisture and 20 foot wind speed, both of which can be obtained from any remote automated weather station, to determine the probability of ignition from small arms tracers.



A screen capture of the TIM Tool user interface.

Benefit

This simple tool can be used to identify specific times when tracer usage is safe, regardless of other conditions. It can be used in conjunction with a fire danger rating system (FDRS), or independently, to help make decisions regarding range usage and weapons restriction requirements. It can also be used as a strategic risk assessment mechanism if coupled with long-term weather data to assess the probability of ignition throughout a day, month, year, or longer, giving range and fire managers a sense for their risk exposure over any timeframe desired, helping to inform firefighter staffing requirements.

The methodology developed here can also be used to validate the 'wet' end of any FDRS in any fuel type. By applying these methods and creating relationships between ignition probability, weather, and fuel conditions, an FDRS can be assessed as to its ability to predict when the ignition probability is low enough to allow tracer use.

Recommendations/Lessons learned

The TIM Tool as it currently stands is applicable to small arms tracer use on guinea grass dominated live-fire ranges. However, the methodology developed during this study is applicable to any ignition source and any fuel type. It should be possible to develop ignition probability equations for any training aid or munition, from handheld flares to artillery, and in any fuel type, from cheatgrass to pine litter.

Though the tool itself is applicable only to military training, a number of observations about ignition probability and guinea grass response to moisture were made along the way. Contrary to common wisdom, guinea grass leaves (though not the stems) behave much like a 1-hour time-lag fuel, meaning it reaches 2/3 of equilibrium moisture content in roughly an hour. Our observations, though not statistically significant, suggest the time-lag of this fuel is in the neighborhood of 75 to 90 minutes.

Communications

The TIM Tool software and its associated information is being distributed to military land managers throughout Hawaii and Guam.

Additional Information

The TIM Tool can be used in conjunction with other fire management tools, such as the Range Impact Probability (RIP) Tool developed under Legacy Project # 10-374. The RIP Tool predicts the spatial probability of impact of a wide variety of weapons on live-fire ranges. By using the RIP Tool to develop a spatial probability and using the TIM Tool combined with long-term weather data to provide a temporal probability, a full picture of ignition probability can be obtained.

Combining the above information with a set of spatial fire behavior simulations via the Fire Area Simulator (FARSITE) or FlamMap can provide a robust assessment of fire probability across a landscape. Such an assessment requires a great deal of expertise, but the payoff is a set of data that captures the full scope of the fire risk, unlike most assessments which only address the hazard posed by fuels, weather, and topography.